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JUNE 1985 · £1·00

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22 WAVEFORM GEN.

CBM 64 MUSIC KEYBOARD

modems

'RUR' HOBBY ROBOT

PE ROBOTICS
MICROS
ELECTRONICS
INTERFACING

ISSN 0032-6372

VOLUME 21 Nº6 JUNE 1985

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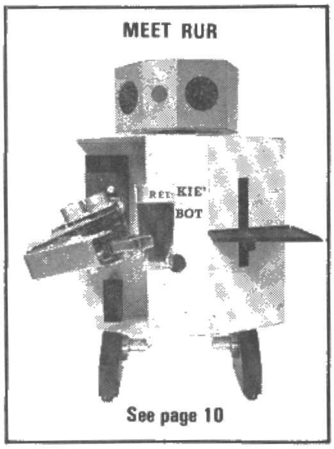
The background of this month's cover shows the "Starsculpture—a living lightening artform", marketed by Markplan Ltd. The display is formed by a microprocessor controlled plasma inside a 12-inch diameter glass sphere.

MEET RUR



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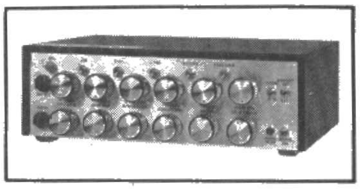

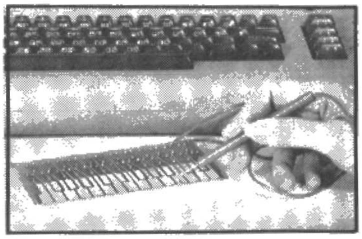

OUR JULY ISSUE WILL BE ON SALE FRIDAY, JUNE 7th, 1985 ***(see page 31)***

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PE VOLUME 21 Nº6 JUNE 1985

WRONG FOR £50m

IT is amazing what some people will do just to prove me wrong. In my March editorial I said "he will need a manufacturer to build the chips since it is highly unlikely that Sinclair will buy or build the necessary factory". Sir Clive is now trying to raise £50 million in an effort to prove me wrong!

Seriously though, I made that statement on the grounds that three large companies had already given up on wafer scale integration. One company—Trilogy (US) having spent more than $200 million (possibly even twice that figure) on research and development over six years to 1984 when the project was abandoned. Sinclair plans to form a company to manufacture WSI chips based on the research into chip production done at his Cambridge centre Metalab. Sinclair's aim is to produce 300,000 seven megabyte chips, based on a four inch wafer, next year. The first product will be a 512K RAM for the QL. To do this he has teamed up with Robb Wilmot, chairman of ICL and ex-head of Texas Instruments in the UK. Between them they plan to raise £50 million venture capital to start the project. Sinclair is being less ambitious than Trilogy—who tried to build a complete processor on a wafer—by starting with memory only. Trilogy's attempt was doomed because of problems with heat distribution and impurities in the silicon itself.

Sinclair's research incorporates the ideas of Ivor Catt, a British inventor who failed to sell his ideas to a number of companies in the 1970's and eventually went to work at Metalab where his ideas were developed and built upon. Providing Sinclair can overcome the heat and impurity problems that result in low yields, he still faces the testing and packaging hurdles which are presently only developed for individual chips. Having said all that, there does seem to be enthusiasm for the idea in financial circles, probably because Robb Wilmot is highly respected in the City.

Sinclair intends to set up a new factory "somewhere in England" to produce the WSI chips. Interestingly, Inmos, now a profitable company, was funded to the tune of £100 million before much in the way of a product started coming out. In 1982 the Inmos annual report showed assets of £20·2 million in freehold land and buildings and £23·7 million in plant and equipment. Inmos had an operating loss for 1982 of £8·6 million. It may be unfair to compare the two start ups—Sir Clive will no doubt not wish to go into the mass memory chip production business and he anticipates a "colossal cost advantage" over "standard" memory chips. Inmos also set up two factories, one being in the USA, and had to start development from scratch. However, it is a similar type of business requiring similar equipment and factory premises and Inmos started spending money in 1978 with the first sample products coming out in 1980.

I hope the £50 million *will* prove me wrong and that my scepticism will be unfounded—only time will tell.

Mike Kenward

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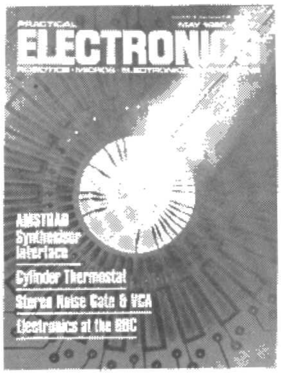

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Components are usually available from advertisers; where we anticipate difficulties a source will be suggested.

Old Projects

We advise readers to check that all parts are still available before commencing any project in a back-dated issue, as we cannot guarantee the indefinite availability of components used. **We are unable to answer letters relating to articles more than five years old.**

Technical *and* **editorial** *queries and letters to:*
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Westover House,
West Quay Road, Poole,
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***Editorial* Poole (0202) 671191**

We regret that lengthy technical enquiries cannot be answered over the telephone.

...NEWS &

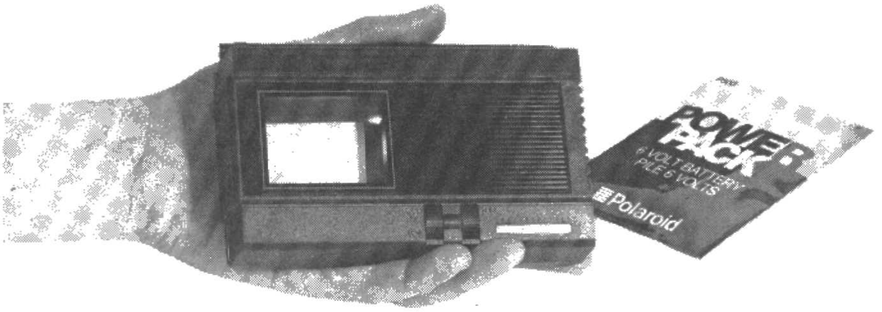
Sinclair's latest

After a heavily publicised 'bad patch' which brought about an indefinite cancellation of the company's floatation on the Stock Market earlier this year Sinclair Research seem to be riding the fiscal storm and are planning more new ventures. The two items featured below are a direct reflection of Sir Clive Sinclair's innovative marketing outlook. They epitomise the type of product that has brought his company's steady expansion (bumpy or otherwise).

In fact the Sinclair 2" flat screen TV was launched as far back as September 1983 but has only been the subject of a reasonable advertising campaign this year. It is the first TV to use a single l.s.i. chip for its circuitry requirements and signal processing functions. Designed by SR and produced by Ferranti Ltd. using the FAB2 CD1 process, it is a complex linear/digital circuit with a number of original advanced features which are subjects of patent applications.

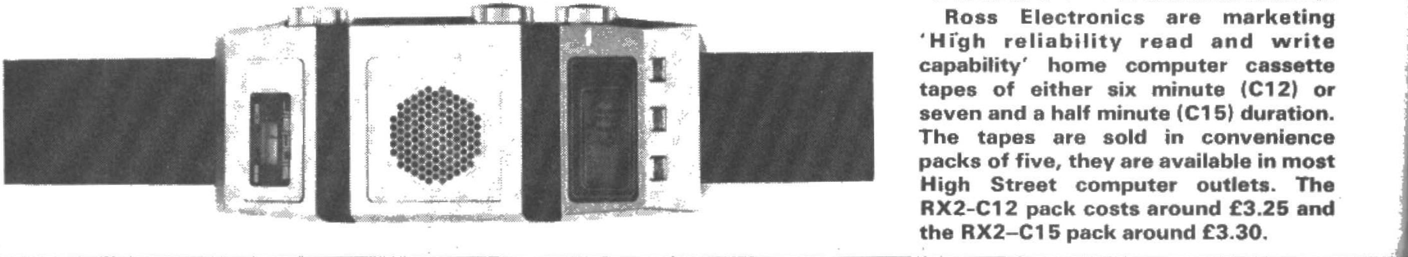
The set uses flat pack batteries by Polaroid which were originally designed for instant film packs. The 6V lithium cells will give up to 15 hours of viewing time. The multi-standard TV is also the first to feature automatic standard switching for reception of most v.h.f. transmissions around the world excluding France.

Measuring 140 × 90 × 30mm the set retails at £99·95 and the 'flat' batteries at £9·95 for a pack of three; a mains adaptor is also available at £7·95.



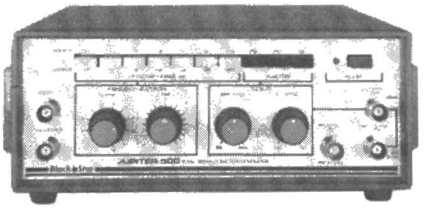
The pictured f.m. wristwatch radio is at present for export to the USA only, it was launched at the Consumer Electronics Show in Las Vegas in January. The product features a full-function digital wristwatch with liquid crystal display and a compact f.m. radio. Unlike its predecessors the radio does not rely on the use of a crystal earpiece, instead the tiny loudspeaker is capable of adequate sound reproduction, or, to quote Sinclair 'remarkable volume'. The radio is powered from a 1·5V battery housed in one of the three hinged parts of the wristlet, allowing up to 20 hours of operation. The antenna is entirely housed within the wristlet and is activated with the clasp. The wristwatch radio will retail for under $100. This and a QL micro sales campaign will spearhead Sinclairs efforts to re-enter the US market.

A £50 million silicon wafer factory is being planned by Sinclair that will provide chips for the scheduled portable minicomputer—Proteus.



Function Generator

The new Jupiter 500 Function Generator is a rugged mains operated instrument offering features unique in its price range, such as full programmability of both amplitude and frequency by external voltage and high output voltage of up to 30V peak-to-peak.



The frequency range is 0·1Hz to 500kHz in seven switched decade ranges with fine frequency control. Sine, square, triangle and TTL (30 loads) waveforms are selectable and an adjustable d.c. offset up to 15V can also be applied to the output. The unit is supplied with a comprehensive instruction manual and sells at £126.50 inc. VAT.

An illustrated colour data sheet is available from: Black Star Limited, 9A Crown Street, St Ives, Huntingdon, Cambs, PE17 4EB. (0480 62440).

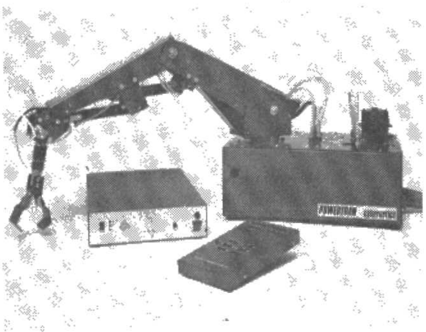
C12's & C15's

If your idea of a good time is sitting in front of the screen with a five-pack then this may be the item for you.

Ross Electronics are marketing 'High reliability read and write capability' home computer cassette tapes of either six minute (C12) or seven and a half minute (C15) duration. The tapes are sold in convenience packs of five, they are available in most High Street computer outlets. The RX2-C12 pack costs around £3.25 and the RX2–C15 pack around £3.30.

MARKET PLACE

MkII GENESIS ROBOTS



Powertran Cybernetics, has now launched Mark II versions of the Genesis programmable hydraulic robots. The Mark II Genesis P101 and P102 are a result of Powertran's policy of continued development rather than a radical redesign, and represent detail improvements over the originals. In addition to the RS232 of the Mark I version, there is now a parallel I/O port.

New manufacturing methods have resulted in closer tolerances for components, minimising operational wear and reducing previously annoying minor hydraulic leakages. At the same time, accessibility to parts requiring servicing or adjustment has been improved.

Despite the wide-ranging improvements in the Mark II versions, prices have remained at reasonable levels, and the Genesis robots still represent a cost-effective introduction to the principles of industrial robotics. Both in construction and operation, the robots mirror industrial robots.

A detailed specification and price list for the new Genesis Mark II robots is available from: Powertran Cybernetics Ltd., Portway Industrial Estate, Andover, Hampshire, SP10 3NN. (0264 64455).

STILL TIME TO CLEAN UP

Until June 25th Bib Audio/Video Products Limited will be running a competition featuring their one-piece push button video head cleaner. This product won a design award in the USA last year for the most innovative consumer electronics product.

A small aerosol is placed inside the VHS cleaner cassette and the push of a button applies a quantity of cleaning fluid to the cleaning tape, this is then run through the machine in the usual way. Because the Beta cassette format is physically smaller than the VHS it does not use the onboard push button method. Instead the cleaning fluid is supplied separately in a small aerosol with a directional applicator.

Back to the competition, the entry forms are included in the packs (where else) and prizes begin with an Autumn/Winter weekend break for two in Paris with £100 spending money. The remaining prizes range from a 14" portable colour TV to video cassette title and label kits.

Both the VHS (pushbutton) and the Beta head cleaners are available from Boots, W. H. Smith, Currys and video stores, they cost £9.98 and £10.99 respectively.

Briefly...

This year Philips Electronic and Associated Industries Ltd. are celebrating their sixtieth year in the UK. During that time its group of companies has applied for and been granted around 20,000 UK patents. This works out at an amazing 'one patent for every working day' since they were first established here in 1925. Current R&D investment is around £1 million per working week.

• • • •

British Telecom inform us that orders in excess of £3 million have already been received for cellphones for use with the new cellular radio network—Cellnet. It is their confident prediction that orders worth £20million will have been placed by the end of the year.

• • • •

The latest catalogue from Cybernetic Application is now available free of charge to PE readers. The publication includes the full range of robotic products available in the Mentor and Neptune ranges; these robots were featured as constructional projects in PE from September 1984 to March 1985.

These constructional articles have been reproduced in the catalogue along with an up to date price list for kits and peripherals. Contact, Cybernetic Applications, Portway Trading Estate, Andover, Hants, SP10 3LF. (0264 50093).

• • • •

Building societies are considering plans to join BACS (The Bankers Automated Clearing Service) which electronically transfers funds between banks and individual companies; kicking cash and cheques even further into touch?

Countdown . . .

Please check dates before setting out, as we cannot *guarantee* the accuracy of the information presented below. Note: some exhibitions may be trade only. If you are organising any electrical/electronics, radio or scientific event, big or small, we shall be glad to include it here. Address details to Mike Abbott.

Apple May 9–11, Novotel, London **L**
Automan (manufacturing) May. NEC **T1**
Electron & BBC May 9–12. New Horticultural Hall, London **L**
IBM Computer User May 14–16. NEC B/ham **O**
Business Telecom May 21–23. Barbican, London **O**
CETEX (Consumer Electronics Trade) May 26–29. Earls Court **M**
Scotelex June 4–6. Royal Highland Soc., Exhibition Hall, Ingliston, Edinburgh **A1**
Software June 4–6. Earls Court, London **K2**
The Computer Fair June 13–16. Earls Court **K2**
Networks June 25–27. Wembley Conf. Cntr. **O**
Cable July 9–11. Metropole, Brighton **O**
Video Software Sept. 1–3, Olympia **G3**
Personal Computer World Show Sept. 18–22. Olympia 2 **M**
Electron & BBC User Sept. 27–29. UMIST, Manchester **L**
Electron & BBC User Nov. 14–17. New Horticultural Hall, London **L**
Computer Graphics Oct. 16–18. Wembley Conf. Cntr. **O**

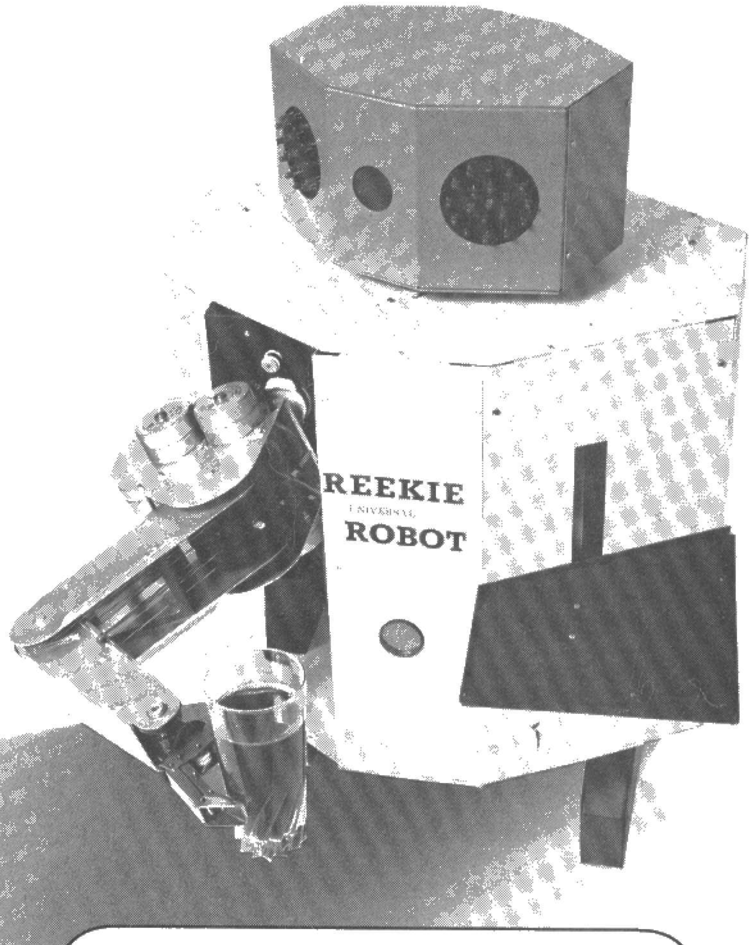
A1	Inst. Electronics ☎ 0706 43661
G3	Link House Video ☎ 01-686 2599
K2	Reed Exhibitions, Surrey Ho., 1 Throwley Way, Sutton, Surrey.
L	Database ☎ 061-429 8157
M	Montbuild ☎ 01-486 1951
O	Online ☎ 01-868 4466
T1	**Cahners** ☎ 0483 38085

THE RUR is a low cost hobby development robot intended for education and enthusiastic electronic and computer users at home.

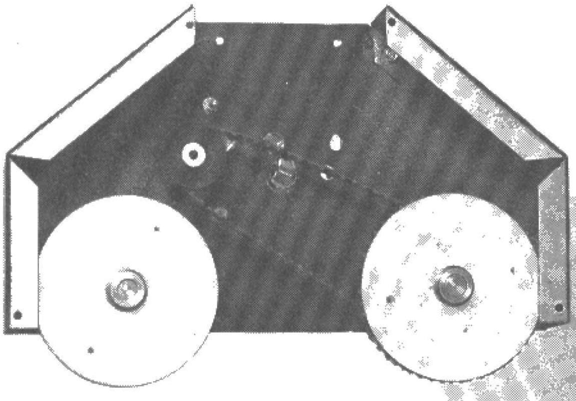
It has the traditional robot shape and brilliant external colours and contains a standard 19 inch rack with provisions for 220mm Euro-Card modules. In its basic form it contains a Z8 c.p.u. control card and motor drive module, which will enable the robot's movement through a Tiny BASIC Teach program. The head is rotatable under software. Two l.e.d. arrays are included in the head to simulate eyes, again controllable by software.

Future plans include optional add-ons such as a remote controlled on-board computer of greater potential having two 16-bit c.p.u.s and expandable up to 1M RAM. The head has built-in positions for the vision system, voice recognition and speech synthesis systems. A sonar detector is included in the basic unit.

The low cost of the robot makes it ideal for micro users with RS232/432 facilities on their host computer and who want to do more with their computer than play games. For education the uses are boundless.



RUR is shown fitted with optional arm and tray



MOBILE
'RUR' HOBBY ROBOT
PART 1

Ralph P. Magee

RUR
REEKIE UNIVERSAL ROBOT

The term RUR was first given to *Rossum's Universal Robot* which featured in a sensational *Karel Capek* play of the early Twenties, performed in both New York and London.

Factory produced "biological androids" took their name *robot* from the Slovak work "Robota", meaning obligatory worker.

The RUR featured now is of more substance than greasepaint, and serves as a mobile test-bed in which experimentation by the lunatic fringe of the hi-tech Eighties need know no bounds. The *Reekie Universal Robot* will not mind you drilling the odd hole in his head to fit some electronics, as long as it's to get him to do something "unconventional".

As they say: "We have the technology," and with *Reekie Engineering's* affordability concept, you might even find you have the money.

SPECIFICATION

Body: Made of aluminium painted in textured yellow.
Shape—Octangular.
Height—480mm.
Width—440mm.
Depth—355mm.
Front of body contains a round aperture of 38mm located 140mm from bottom of body in a central position which will contain a sonar detector. The right hand-side has a provision for a future belt driven arm *and not* "Springs and Strings" as illustrated in the prototype. A standard Vero 19 inch rack is placed vertically towards the rear.

Feet: Made of aluminium and coloured matt black.
Toe to heel—240mm.
Height—From floor to bottom of body 185mm.
Motivation power is supplied by two (one in each foot) 12 volt d.c. motors with gearbox by Crouzet Ltd. of 60:1 ratio, shaft speed 60 rpm.

Head: Made of aluminium. Colour—deep textured orange.
Shape—Octangular.
Size side to side—277mm. Front to back—220mm.
Height—155mm.
Each side of front face contains an aperture of 76mm with 19 l.e.d.s. central front—an aperture of 38mm for future vision system or a second sonar. On each side suitable holes can be made to accept microphones for voice recognition and on top a speaker space for voice synthesis. Head rotation is by a 12 volt d.c. motor with gearbox by Crouzet Ltd. of 120 rpm.

Electronics: Z8 c.p.u. controller with 2K RAM 4K EPROM and tiny BASIC interpreter which will receive and transmit with host computer by cable using the RS 232/432 port.
Driver module—Darlington and 6 d.c. relays.

D.C. Battery: Sealed lead acid 12 volt 5Ah made by Gates Energy Products is supplied.

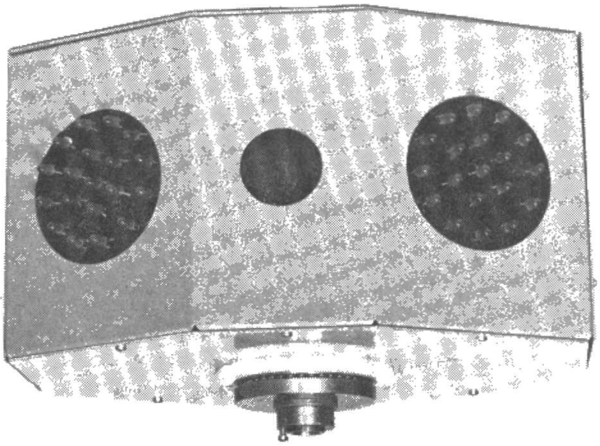
Future Optional Add-ons

1) Belt drive arm by Reekie and an elevated tray unit plus hardware for steppers. Robot will then have 10 degrees of freedom.
2) Control card containing two 16-bit c.p.u.s and up to 32K RAM. Full BASIC and QWERTY keyboard. This will also contain on the keyboard an l.c.d. read-out.
3) Speech synthesis.
4) Voice recognition.
5) Vision system.

MECHANICAL ASSEMBLY—BASE

Screw front and rear extrusions onto base section (the one with no hole in the centre), using M4, 12mm screws. This is now the base of the body. Next attach top to these extrusions, and place Rack Module guides into slots as needed. We suggest topmost position for the electronics basic kit.

The bearing assembly should now be placed in the hole provided in the top section and screwed down. This bearing is used for attaching the head to the body. Fix into position, forward of the bearing, one 12 volt motor (the one with the red dot) using M3, 6mm screws and nuts.



The RUR head incorporates 'eye-catching' l.e.d. eyes, and a hole for an ultrasonic range-finder. The swivel bearing can also be seen

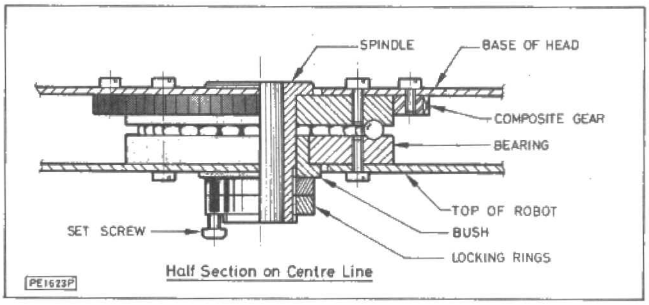


Fig. 1. The head ball bearing assembly

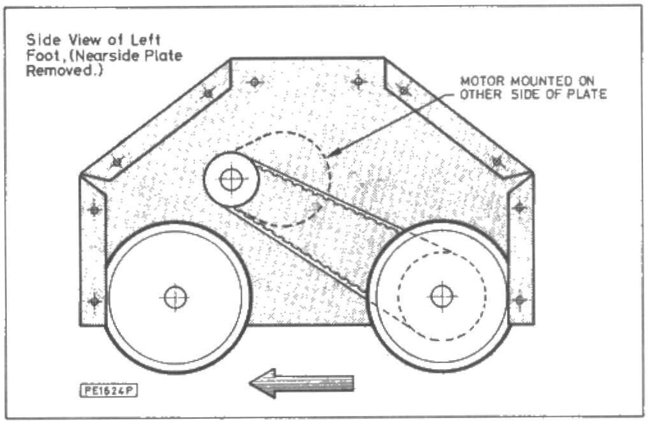

Side View of Left Foot, (Nearside Plate Removed.)
MOTOR MOUNTED ON OTHER SIDE OF PLATE
PE1624P

Fig. 2. Foot drive system. Only one wheel is driven

Using N4, 6mm self-tap screws fix the 185mm left section into position "b". Fix 130mm width section onto the front "d". Now the front left section of 175mm to side "c". Using care, slide large shaped section to right of body and screw into position using self tap N4, 6mm screws position "e".

Body now has in position the top and bottom, left, right and front left. The rear-left and rear-right has been left open for now to give access for later assemblies.

COMPONENTS . . .

Mechanical

Body

Top unit of body	
Bottom unit of body	
Left side	
Right side	
Front left	
Rear left	
Front	
Preformed support strips	(4 off)
Rear right	
Front extrusions	(2 off)
Rear extrusions	(2 off)
3U/10E extended 4 rail module kit	
Module guide	(10 off)
12V d.c. motors with gear box	
Sonar kit	
Relays	(6 off)

Feet

Right and left sections inner	(2 off)
outer	(2 off)
Inner, outer spacers	(8 off)
Wheels	(4 off)
Pulleys	(2 off)
Belts	(2 off)
Motors	2

Head

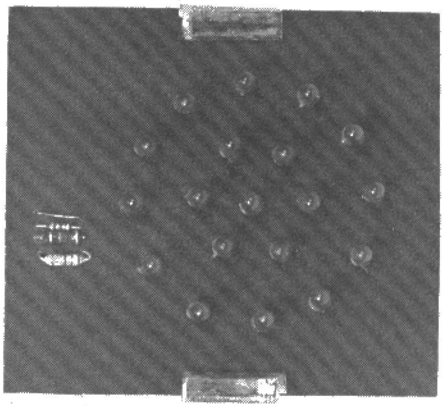
Front shaped unit	1
Rear shaped unit	1
Top	1
Bottom	1
Sides	2
Bearing assy	1
L.e.d. arrays	2

Miscellaneous

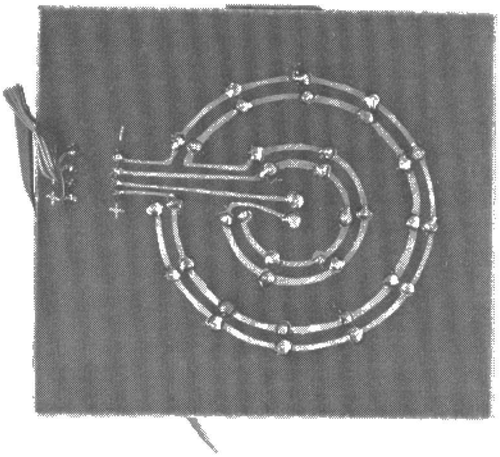
M3 Screws and nuts	1 Pk
M4 Screws and nuts	1 Pk
N4 Self tap screws	1 Pk
Battery 12 5Ah	1
Wire (supplied to suit)	
Ribbon cable	3 metres

Constructor's Note

A full kit of parts for the RUR is available from **Reekie Robots, Beaufort Works, Beaufort Road, Richmond Road, East Twickenham, Middlesex TW1 2PQ.** ✆ 01-892 2877. Prices are as follows: *Basic kit:* £249 plus VAT. *Add-on Arm and elevated tray:* £280 plus VAT.



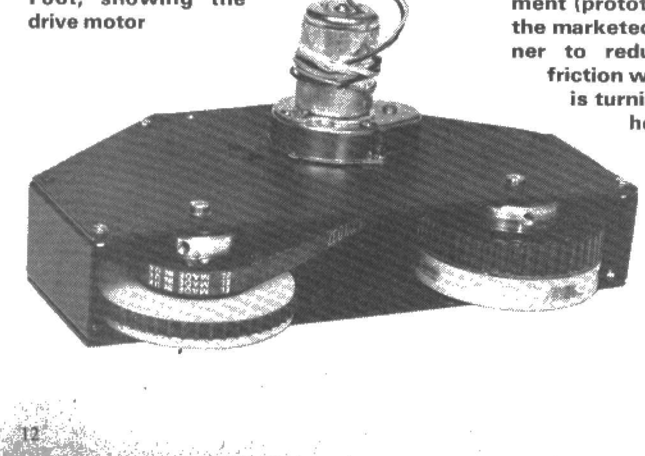
An l.e.d. eye p.c.b. (prototype)



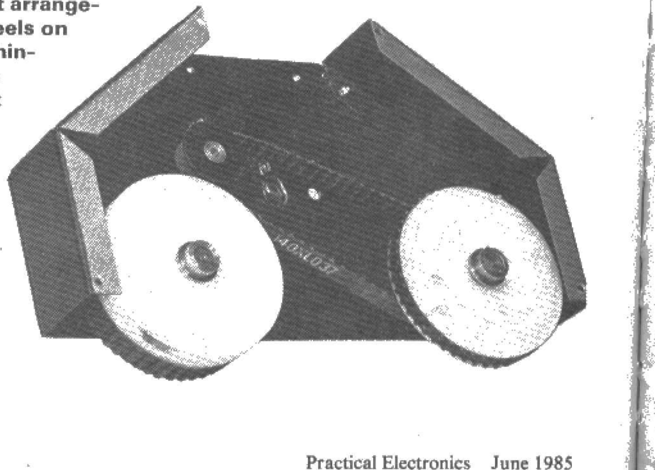
The track-side of the eye p.c.b. Note that the l.e.d.s may be illuminated in rings—outer, inner, and centre (single) l.e.d.

RUR incorporates ultrasonic range-finder module

Foot, showing the drive motor



Foot, showing internal belt arrangement (prototype). The wheels on the marketed version are thinner to reduce sideways friction whilst the robot is turning to a new heading



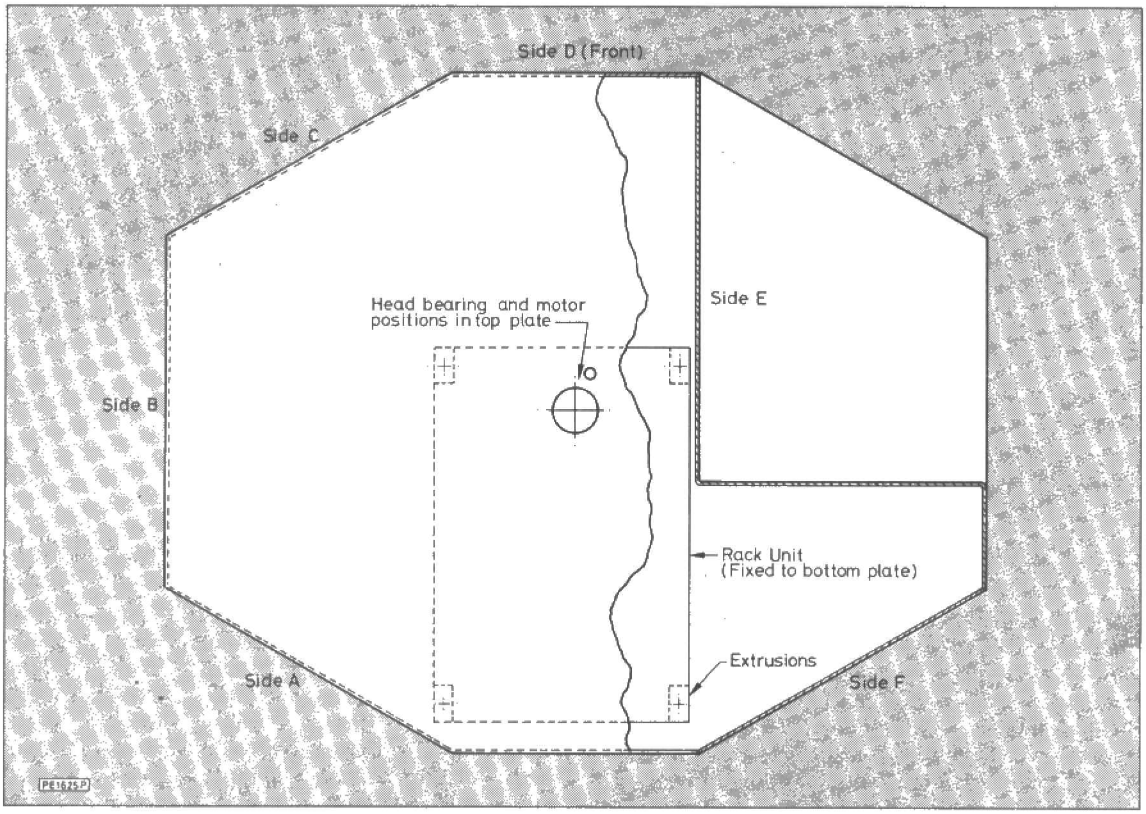
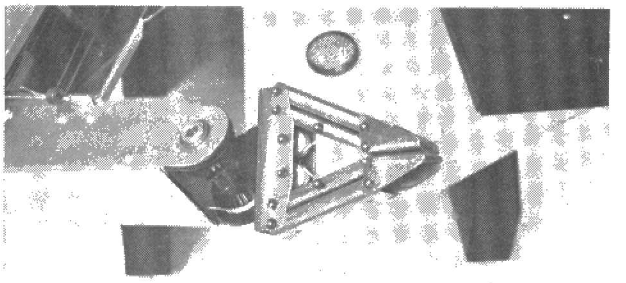
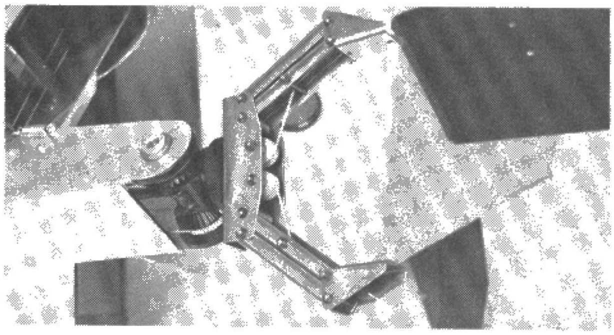

Side D (Front)
Side C
Side B
Side A
Side E
Side F
Head bearing and motor positions in top plate
Rack Unit (Fixed to bottom plate)
Extrusions
PE1625P

Fig. 3. Plan view of the RUR body. Also housed within the body is a specially manufactured lead-acid battery power source



The optional arm (Armdroid unit) with gripper closed



The optional arm with gripper open

MECHANICAL ASSEMBLY—HEAD

The head is in six sections; shaped front and rear, top and bottom and two sides. Using N4, 6mm self tap screws fit rear to bottom. Using the double-sided sticky tape position the l.e.d. arrays into the eyes. Attach front section on to bottom as in the rear assembly.

Using M3 screws attach the head onto the bearing assembly that has been positioned on the body.

Using N4, 6mm self-tap screws assemble the left and right sides. Thread the ribbon cables from the l.e.d.s through the bearing hole. Finally, attach top using N4, 6mm self-tap screws.

MECHANICAL ASSEMBLY—FEET

The feet are assembled using the two similar shaped sections for each foot. The inner section is distinguished by the hole provided for the motor.

Firstly attach the motor (with blue dot) into position using M3, 12mm screws and nuts. Do not tighten at this stage.

Attach large diameter shafts on to position A and B. Place rear wheel on shaft and pulley on motor shaft. Now place belt over motor pulley and then over the provision on the rear wheel. Take up any slack from the motor end and tighten all screws. The belt should be comfortably tight.

Attach 12mm fixing brackets to the inner and outer feet sections and assemble them together using the spacer sections at positions CDEF. This is now one foot. Use the same method for assembling the other foot.

Now attach the feet to the bottom of the Robot using M4, 12mm screws and nuts. Feed the motor wires through the holes provided.

NEXT MONTH. The electronics, software and use.

modems

M. TOOLEY BA and D. WHITFIELD MA MSc CEng MIEE

Electronic Mail, On-line Databases, and Bulletin Boards are all terms in widespread use by the computer press today. However, like many such terms these are products of the inexorable computer jargon machine, and are often not quite as widely understood. Indeed, to many, the only mental image conjured up by the term Electronic Mail is that of components for the latest *PE* project arriving by post! Underlying all three of these terms, however, is the concept of computers communicating with each other over telephone lines. In this and two subsequent articles we shall be examining the basic principles of this type of computer communications, and in this first article we start by looking at the basic tool of micro communications; the modem.

COMMUNICATING BY PHONE

The basic idea behind computer communications is straightforward enough; it is to send information from one computer to another in a form that can be received and understood by the recipient. However, as with most simple ideas, the practical processes which are involved are a little more complicated than this simple statement might lead us to believe. By looking into the problem a little more closely to see what is involved, we will be much more likely to be able to make sense of the manufacturers' specifications, and therefore solve any practical problems which may arise at a later date.

To begin with, let us suppose that we have two computers, in different locations, and we wish to send a message between the two. Typically this message could be a file which is to be transferred between the two systems, but it could equally well be any other collection of bytes stored in memory, or even generated by a program. Starting from this point, we must provide a mechanism whereby the recipient receives a copy of our "message" in his computer's memory.

At one time, this problem would have been approached by the use of special data lines to link the users together. However, this obviously lacks appeal, particularly where communication is required infrequently and/or with a number of different and remote locations. Instead, the problem is now usually solved by using standard (voice) telephone lines to provide the basic link (the communications bearer) between the two computers. However, a telephone line is a single audio channel, and is not immediately suitable for transmitting the parallel digital data found inside a computer. Furthermore, the parallel buses inside the computer operate at high frequencies (often above 1MHz), whereas the frequency response of a standard British Telecom line is limited to a bandwidth of approximately 3kHz. While this is quite adequate for speech (and even music can be recognisable), something must obviously be done if data transmission is to be successful. A further complication (and there always is one!) is that some frequencies within the audio range are also used for tone signalling within the BT network.

Overall, the basic problem of transferring data over a telephone line breaks down into three major parts, shown in block schematic in Fig. 1. First, the message data must be extracted from the computer in a form suitable for slow speed serial transmission. Second, the digital data must be converted into a form which matches the capabilities of the telephone line. The corresponding reverse operations are also required at the receiving end. Only then are we ready to worry about the final component in the overall transfer process; the software. We start, however, by looking at the problem of serialising the parallel data in the computer.

SERIAL INTERFACE

Most home and small business computers either come fitted with a serial interface as standard, or can have one fitted as an option. This interface usually conforms to either the RS232C or RS423 standard (although not always exactly as regards the connectors used). However, for our purposes there are few practical differences, and functionally we usually consider the two standards to be identical. For convenience we shall refer to this type of interface as the RS232 port, but what exactly does an RS232 port do for us?

The short answer is that this port provides us with just the facility we are looking for; it takes parallel data from the computer's bus, and turns it into a serial bit stream, and vice versa. This conversion is usually performed by a special purpose computer peripheral i.c., known as an Asynchronous Communications Interface Adaptor (ACIA), which is connected to the computer's system bus. There is a little more to the process than this, however, and if we leave the

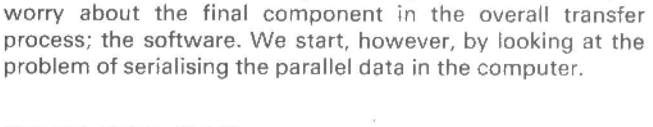


Fig. 1. Computer communications by telephone

problem here we may become hopelessly lost when we actually try to make our communications link work.

The RS232 standard covers all of the pins available on the 25-pin D-type connector specified, but in this application only a few of these signals are actually involved; these are shown in Table 1. Unfortunately, the connectors used by the various computer manufacturers do not all follow the RS232 standard, or even the same variation on the standard. The connectors for the "standard" RS232 (D-type), and the BBC Micro's serial port (DIN domino type) are shown by way of example in Fig. 2. One of the reasons for these deviations from the standard is undoubtedly the cost involved in providing a full RS232 interface, when only a small proportion of the signals are actually required. The points to note here are: always check which signals you actually require, and make sure that you have the appropriate lead for your computer.

RS232 Pin	Signal
1	Protective Ground
2	Transmitted Data (TXD)
3	Received Data (RXD)
4	Request to Send (RTS)
5	Clear to Send (CTS)

Table 1. Commonly used RS232 signals

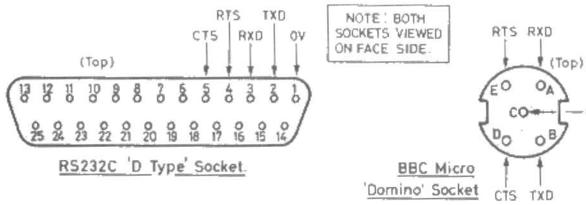


Fig. 2. Serial port connectors

Basically a serial interface consists of a Data In line, a Data Out line and a Ground connection. This represents the barest minimum for a bidirectional serial link, although handshaking lines are often supplied in addition, but are not essential. When these handshake lines are used, data should only be sent out from the micro when CTS (Clear To Send) is low, whereas the micro should set RTS (Ready To Send) low when ready to receive data. If a software handshake is used instead of the hardware handshake, connecting RTS to CTS will usually produce a simple 3-line link.

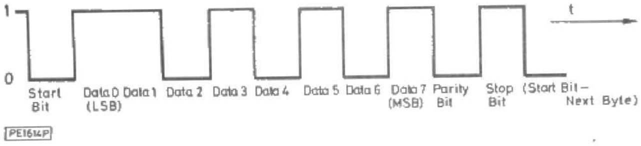


Fig. 3. Serial data byte waveform

The data itself is transmitted serially using a format which must be agreed in advance between the sender and receiver. The general form of the serial data stream is shown in Fig. 3. The voltage range for RS232 signals is shown in Fig. 4, and in practice levels of around ±12 volts are commonly used for logic 1 and 0, respectively. As we can see, the data bits for each character are sandwiched between a start bit at the beginning to indicate that a character follows, and a selection of parity/stop bits at the end. The parity bit (if present) allows the receiver to check that the parity is correct; if not, there has been an error somewhere between sender and receiver.

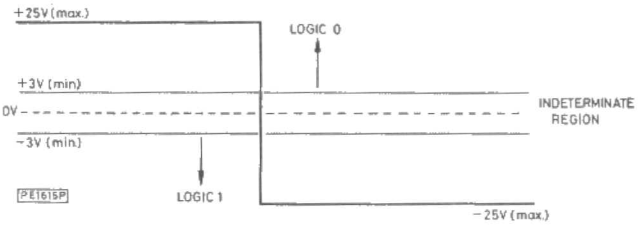


Fig. 4. RS232 voltage levels

As we have suggested, there are a number of different arrangements which can be used for the serial data stream. The example in Fig. 3 shows 8 data bits per frame, with odd parity and one stop bit. Table 2 shows typical combinations which may be encountered; selection is usually performed by software (e.g. using a *FX151 call on the BBC Micro).

Start Bit	Data Bits	Parity	Stop Bits
1	7	Even	2
1	7	Odd	2
1	7	Even	1
1	7	Odd	1
1	8	None	2
1	8	None	1
1	8	Even	1
1	8	Odd	1

Table 2. Common data stream formats

The most important point to note, however, is that whatever combination of data, parity and stop bits is selected, both ends of the link *must* be using the same settings if there is to be any hope of successful communication.

There is one final characteristic of the serial data stream which we must consider before we leave the subject; that of data rate. The waveform in Fig. 3 shows the format of the frame used to send one character, but it contains no actual time values. The duration of a single bit determines the rate at which data can be carried by the serial stream. For example, a 1msec bit duration allows a maximum of 1000 bits to be transferred in a second. This rate is known as the baud rate. Thus a baud rate of 1000 means that if we use one start bit, 8 data bits, 1 parity bit and 1 stop bit, we can send a maximum of around 91 bytes per second over the link.

We have now considered all of the factors which are required in order to specify our data stream to another user, and for convenience these are summarised in Table 3,

Characteristic	Typical Values
Baud Rate	75, 300, 600, 1200
Data Bits	7, 8
Start Bits	1
Parity	Odd, Even, None
Stop Bits	1, 2

Table 3. Serial data stream characteristics

together with typical values. Having produced the bit stream, the next step is to consider the problem of how to squeeze the digital signal from the RS232 port down an analogue telephone line.

MODEMS

The word modem is derived from the term MOdulator-DEModulator, and neatly describes the function of a modem as being to modulate signals onto a carrier, and to demodulate signals from a carrier. In this case the carriers referred to are audio signals falling within the frequency range of a telephone line, and the modulation is something which is controlled by the serial data stream. The almost universally adopted modulation technique for this purpose is known as Frequency Shift Keying (FSK). In this technique a binary 0 (also known as a space) is represented by one tone, while a binary 1 (also known as a mark) is represented by another nearby.

The overall bandwidth of the telephone line clearly affects the range of tones which can be used in FSK. Although not immediately quite so obvious, the line bandwidth also affects how often these tones may be switched (keyed) between mark and space. Overall, the practical maximum data rate which can be supported by a telephone line comes out at around 1300 baud. By sharing out this available capacity in different ways, however, we can set up one-way links, or two-way simultaneous links on a single telephone line. The two-way type of link is known as a full-duplex link. Alternatively, we can set up two-way links that are used in only one direction at a time. These are known as half-duplex links, and clearly require some agreed method of changing over from one sender to the other. Half-duplex links do, however, allow us to use the maximum speed in each direction, and hence reduce call costs by minimising the time required to transfer a message. To complete the picture, the final type of link (not much used) is the one-way or simplex link. So much for the principle, but how do we get two-way operation onto a single telephone line?

The basic arrangement of a modem linked to a telephone line is shown in Fig. 5. If both ends of the link used the same frequencies to transmit, it is clear that there would be severe interference problems. Instead, each end of the link is allocated a different pair of frequencies for sending data. The receiver section in each modem is also provided with a bandpass filter which rejects its own signals, and accepts only those in the range allocated to the other user. There must obviously be agreement between the two users as to who sends which set of frequencies, and therefore each is designated (and set up) as *either* Originate *or* Answer mode. When talking to large systems, users are invariably originating the call, and hence operate in originate mode. In user to user links, however, it is a matter for local arrangement.

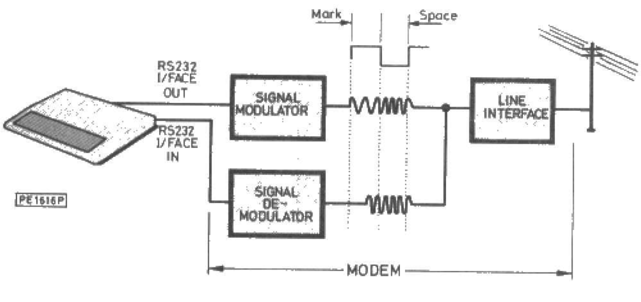
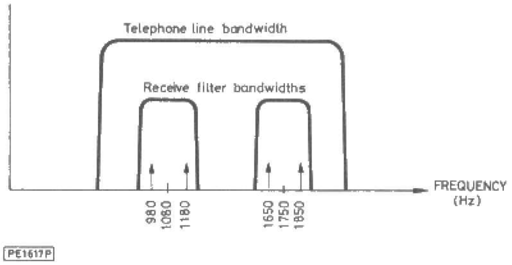


Fig. 5. Basic modem configuration

Mode	Baud Rate	Transmit Frequency		Receive Frequency		Duplex
		Space (Hz)	Mark (Hz)	Space (Hz)	Mark (Hz)	
CCITT V.21 Orig	300	1180	980	1850	1650	full
CCITT V.21 Answer	300	1850	1650	1180	980	full
CCITT V.23 Mode 1	600	1700	1300	1700	1300	half
CCITT V.23 Mode 2	1200	2100	1300	2100	1300	half
CCITT V.23 Back	75	450	390	450	390	—
Bell 103 Orig	300	1070	1270	2025	2225	full
Bell 103 Answer	300	2025	2225	1070	1270	full
Bell 202	1200	2200	1200	2200	1200	half

Table 4. Signal frequencies



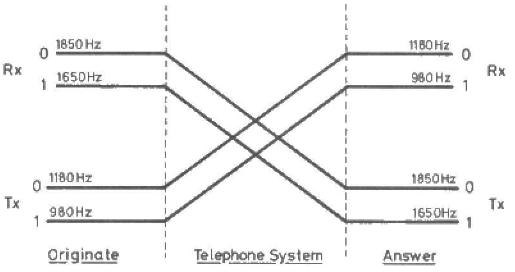


Fig. 6. V21 channels for 300/300 baud

The frequencies used by the Answer and Originate users are invariably specified from one of the internationally agreed standards. These depend on the data rate to be used, the continent (i.e. USA or Europe), and whether the user is operating in Answer or Originate mode. The USA uses a series of standards set up by the Bell Telephone System, whereas in Europe the CCITT standards have been adopted. The frequencies used are shown in Table 4, and Fig. 6 shows an example of how the commonly used 300 baud send/receive V21 channels are allocated. The modes which a modem can support will depend on the frequencies that it can generate and, more difficult, the frequencies to which the receiver filter can be switched. The early single-mode modems are now being joined by multi-mode types. We shall be seeing next month how LSI technology has helped to bring about these changes in the modem market.

Typically, micro users have tended to adopt one of two baud rates. For user-to-user communication 300/300 baud is the normal choice, whereas for on-line databases and dial-up services like Prestel, a 1200/75 baud arrangement is the normal choice. This latter choice is based on the fact that this type of system sends a lot of information to the subscriber, but the user's response is typed at a relatively slow rate. As can be seen, the use to which a modem is to be put will affect the range of modes which must be supported. Multi-mode modems are now increasingly available at prices which compare very favourably with single-mode types and these can solve the problem of choosing the appropriate speed at the time of purchase.

So far we have seen how a modem converts the bit stream from the computer's serial port into audio tones suitable for a standard telephone line. The demodulator side of the modem will be able to recover this bit stream from the incoming audio signal. The next problem in the computer-to-computer link is how to connect the modem to the telephone line.

MAKING CONNECTIONS

There are basically two methods of connecting a modem to the BT network; acoustically and direct. These methods are illustrated diagramatically in Fig. 7. All modems connected to the BT network must be approved by BABT, and must carry the appropriate green approval sticker.

In an acoustically coupled modem a 'reverse' telephone handset is provided which has a small microphone and loudspeaker. These are arranged so that they are opposite the normal handset's earpiece and mouthpiece, respectively, when the two are physically coupled. Data to be sent is output to the loudspeaker, while received data is picked up from the microphone. The reverse telephone usually has some type of wrap-around rubber coupling to provide good sound isolation from background noise. The advantage of the acoustic coupler is that the modem remains electrically isolated from the BT network. The disadvantage is that the coupler is sensitive to background noise and vibration, and is not always suitable for non-standard handsets.

The directly coupled modem connects to the BT network using one of the new-style modular plugs. Although called 'direct', the part of the modem running off its own power *must* be electrically isolated from the network. This is usually done by means of a line isolating transformer, or increasingly by an opto-isolator. The point of this is to prevent accidental application of dangerous voltages (mains in particular) to the line, which otherwise could have dangerous effects on people and equipment. The direct connect modem avoids the problems inherent in the acoustically coupled modem, and at long last prices are now falling to a comparable level. All direct connect modems must be BT approved.

We now have the complete link from computer to computer via the telephone network. All that remains is to sort out the software we need in order to be able to actually use the link.

SOFTWARE

As with anything involving a computer, the communications link just described (computer, serial port, modem and telephone line) is useless without suitable software. It could be said that the communications software will be the most important factor in determining how easy to use and how versatile the system will be, but what is it that this communications software is required to do?

The basic language of computer communications is ASCII (American Standard Code for Information Interchange); an internationally accepted standard 7-bit code for characters (also including a range of control codes). All messages sent and received between computers are usually serial bit streams representing ASCII characters. The first requirement of any communications software, therefore, is to be able to convert data from the computer's internal storage format to ASCII, and vice versa. With text, which constitutes the majority of messages, this is not usually too difficult since most computers store text as one ASCII character in each byte. This facility also implies an ability in the software to be able to interface with the computer's memory and/or filing system. At this point it rapidly becomes clear that communications software is almost invariably specific to a particular machine; some is even specific to one modem.

Next, the software must be able to set up and control both the modem and serial port. This should support at least 300 and 1200 baud settings. Some modems can actually be set up under software control, rather than via front panel switches. This will, however, require that the appropriate facilities are included in the software. The communications software must clearly be able to handle both the incoming and outgoing data streams. This will require the ability to

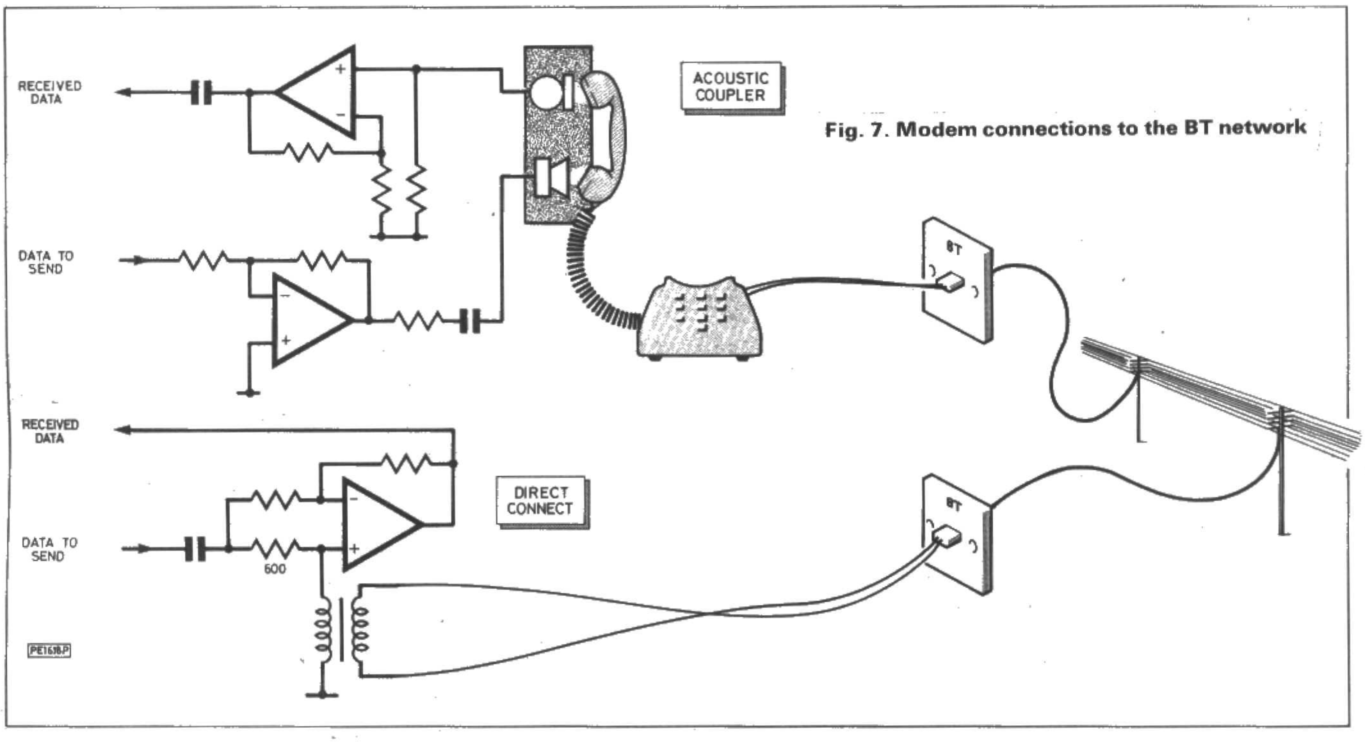


Fig. 7. Modem connections to the BT network

specify the source and destination of data, preferably providing a choice between RAM and the filing system. If you wish to transfer files using software handshake protocols, these must also be supported by the software (e.g. XON/XOFF).

The facilities just described represent the minimum that is required to get "on line". When selecting a suitable software package, it is important to choose one which is easy to use. Preferably, the software should be menu-driven, since this will make it easier to use without continuous reference to manuals. Further facilities will be useful if you intend to make significant use of an on-line database, e.g. Prestel. For example, the facility to dump a screen to the filing system for later study or printing will prove useful, and will reduce the connection time (and hence cost!). Similarly, the ability to prepare messages off-line, and then call them up from the filing system when actually on-line, will also save connection time.

As we have said, the communications software will have a significant effect on the ease of use of both the modem and any on-line service. With this in mind, it is essential that a software package is chosen which meets your needs in the most straightforward possible manner. Look around for a suitable package, and try to compare a few likely candidates at work, but be prepared to spend up to around £30 for a good package. Money spent on the *right* package, however, will be money well spent.

MORE MODEM FACILITIES

To conclude this first article we will now look at additional facilites offered by some of today's more sophisticated modems. None of these are essential features, but many are attractive, and can widen the range of uses for a modem. The first three all require software to support their use.

Software control: Some modems allow various settings (e.g. speed) to be controlled from the computer, as an alternative to using the normal front panel switches.This usually requires an appropriate port on the computer (e.g. the user port on the BBC Micro), and an extra lead.

Auto answer: This option in a modem works rather like a telephone answering machine. If your telephone number is rung, the modem answers with a tone; a corresponding tone indicates that the caller is another computer, and communications can then continue automatically. This feature can be extremely useful, for example, to allow messages to be left when you are not at home (or asleep!).

Auto dial: This feature allows telephone numbers to be rung directly from the computer. This allows directories of numbers to be held on (say) disc. Getting the computer to periodically re-dial engaged numbers is another useful benefit.

Auto speed selection: When calling another computer, the answer tone will allow the mode and speed to be detected; see Table 4. This allows the modem's mode and speed to be set up automatically.

NEXT MONTH: We shall be looking at the techniques available for building a modem.

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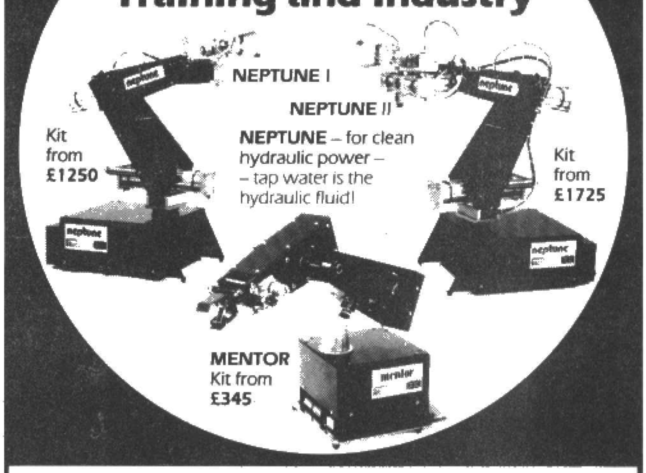
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DATA CONVERTER (ZN435)

As more and more functions and facilities are combined within integrated circuits, it becomes tempting to treat them purely as 'black boxes', without any real regard for what goes on inside. This is particularly true of many analogue to digital ('A to D') converters, where we are rarely aware of the activity within the devices, so are unable to significantly change the way in which they work. Conversely, A to D converters which do allow us access to their internal working are often very difficult to use. Against this background, the ZN435 from Ferranti comes as a breath of fresh air! It's a very simple to use device, yet can act as an A to D converter, a D to A converter, a voltage to frequency converter, and much more. The pinout of the ZN435 is shown in Fig. 1, and its specifications in Fig. 2—there are quite a number of specifications for the i.c. due to the number of different circuit blocks contained within it.

BLOCK OPERATION

The block diagram of the i.c. is shown in Fig. 3, the basic 'building blocks' being a D to A converter, a voltage reference, an up/down counter, and a clock oscillator. The D to A converter can be controlled by either the internal 8-bit up/down counter, or an external 8-bit code, as determined by the input select switch. When the D to A converter is receiving its data from the internal counter, this data is also made available at the digital input/output pins.

The on-chip oscillator is used to drive the counter, although this may be over-ridden by an external clock signal. Likewise, an internal voltage reference is provided for use by the D to A converter, although an external reference may be used if preferred.

DIGITAL CONTROL

The control logic determines the actions of the internal up/down counter, and controls the digital input selection switching, as shown in Fig. 4. The $\overline{\text{UP}}$ and $\overline{\text{DOWN}}$ inputs are fairly self-explanatory, and select the normal direction of counting. Both $\overline{\text{UP}}$ and $\overline{\text{DOWN}}$ inputs in the logic 1 state will cause the counter to be stopped, and both at logic 0 (with MODE at logic 1) allows the counter to count up to its maximum, then down to zero, then up to maximum again, etc. The MODE input determines the action of the counter at zero and at its full-scale maximum count of 255. When the mode input is at logic 1, the counter will reset to zero if it exceeds 255 in the up direction, and will jump to 255 if it goes beyond zero in the down direction. With the mode input at logic 0, the counter will stop on reaching the full-scale maximum count in the up direction or zero in the down direction. If MODE, $\overline{\text{UP}}$, and $\overline{\text{DOWN}}$ are all held at logic 0, the i.c. is placed into the 'digital to analogue converter' mode. In this mode, the input select switch turns off the outputs of the up/down counter, forcing them into a high impedance state and allowing the digital inputs/outputs (pins 1 to 8) to be used as inputs to the converter. In all other modes of operation these input/output pins are used as outputs from the counter. Finally, a logic 0 on the $\overline{\text{RESET}}$ pin will reset the counter to zero in any of the modes. The digital inputs/outputs can be driven from, or can drive into (as appropriate) all 'B' series, CMOS, ordinary TTL, LS TTL, and other compatible logic families.

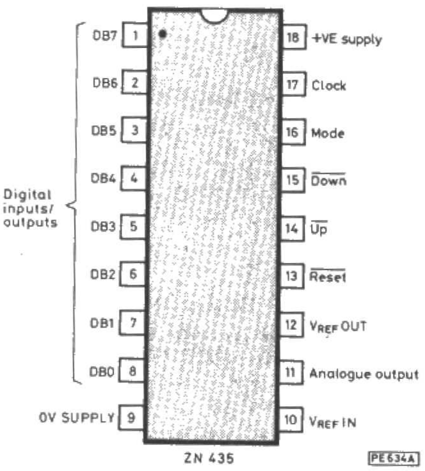


Fig. 1. Pinout

THE CLOCK

The internal clock can be operated by taking a resistor from pin 17 to the positive supply, and a capacitor from pin 17 to 0 volts. The frequency of oscillation is given by the formula:

$$f = \frac{1}{2RC}$$

(f is in Hz, R is in ohms, and C in farads.) Fig. 5 shows a graph of typical values against frequency. Note the limits of 3k to 100k on the resistance value, and 100pF on capacitance, as shown in the specifications. At low capacitances (less than 1nF) there is likely to be an error in the frequency obtained; it won't correspond exactly with the formula or the graph. If such an error does occur, it will be due to manufacturing tolerances of the lower clock voltage threshold, and possibly due also to stray capacitance in the circuitry and wiring around pin 17 of the i.c.

If it is required to use an external clock, then the internal clock must be over-driven by the external one. When doing this, the external timing resistor and capacitor are omitted. TTL or LS TTL signals can drive pin 17 directly, with no further circuitry being necessary. Open collector or open drain logic outputs must use the arrangement of resistors shown in Fig. 6a, and CMOS logic must use the circuit shown in Fig. 6b. In all cases the high level (logic 1) clock driving signal at pin 17 must be attenuated to below 4·5V, since a signal above this voltage will cause damage to the internal clock circuitry. The upper frequency limit is guaranteed to be 1MHz or better.

THE D TO A CONVERTER

The digital to analogue converter is a voltage switching type with a very low offset voltage of typically 3 to 5mV. Ignoring offsets, the output voltage is given by the formula:

$$\text{output voltage} = \frac{(V_{\text{ref}}\text{IN})N}{256}$$

'N' is the decimal equivalent (i.e. 0 to 255) of the binary number fed into the D to A converter. The output impedance of the converter is typically 4k, so buffering should be provided prior to any low impedance load. The input voltage to the converter, V_{ref} IN, can be any voltage in the range 0 to 3·0V.

An internal voltage reference is available, if required, for feeding into the converter—or for any other purpose, for that matter. This is equivalent to a 2·6 volt Zener diode with a very low slope resistance, giving good stability. A pull-up resistor must be provided from the V_{ref} OUT pin (pin 12) to the positive supply rail. The recommended value of 390 ohms will allow a nominal reference current of 6·4mA to flow, which is sufficient to drive the V_{ref} IN pins of up to five ZN435s simultaneously, if a number are required to track together closely in a system. The V_{ref} OUT pin should be decoupled to 0V by a

Characteristic		Notes		Minimum Value	Typically	Maximum Value	Units
	Supply voltage	Unless otherwise specified, spec's measured at +5V supply		4·5	5	5·5	V
	Quiescent current	+ 5·5V supply			35	45	mA
	Temperature range	ZN435E		0		+70	°C
		ZN435J		−55		+125	°C
D to A converter	Linearity error	Over full temperature range			±0·25	±0·5	L.S.B.
	Differential linearity error	Over full temperature range			±0·25	±1·0	L.S.B.
	Zero error (All bits off)	ZN435E			3·0	5·0	mV
		ZN435J			5·0	10·0	mV
	Maximum settling time	To 0·5 L.S.B.			800		ns
	Full scale output	All bits on, V_{ref} IN = 2·560V		2·545	2·550	2·555	V
	Output resistance				4		kΩ
	Output temp. coefficient	Full scale output, V_{ref} IN = 2·560V			4		ppm/°C
	V IN voltage range	At pin 10		0		3·0	V
Voltage reference	Output voltage	Measured at pin 12. Pull-up resistor from pin 12 To +ve supply = 390Ω Decoupling capacitor from pin 12 To 0V = 220n		2·4	2·59	2·7	V
	Slope resistance				2	4	Ω
	Temperature coefficient				50		ppm/°C
	Output current			4·0		15	mA
Internal clock oscillator	Maximum frequency			500			kHz
	Temp. coeff. of frequency				100		ppm/°C
	Frequency spread	Device to device, using the same resistor and capacitor				1·0	%
	Clock resistor	Between pin 17 and +ve supply		3·0		100	kΩ
	Clock capacitor	Between pin 17 and 0V		100			pF
	High level threshold				4·6		V
	Low level threshold				1·5		V
Counter	High level threshold	At clock input, when using an external clock				2·3	V
	Low level threshold			1·7			V
	Maximum frequency			1·0	1·5		MHz
Control inputs	High level I/P voltage	For logic 1 level	Pins 13, 14, 15 and 16	2·0			V
	Low level I/P voltage	For logic 0 level				0·8	V
	High level I/P current	Input voltage = 2·4V				−25	μA
	Low level I/P current	Input voltage = 0·4V				−95	μA
	Reset pulse width	At pin 13		200			ns
Digital inputs	High level I/P voltage	For logic 1 level	Pins 1 to 8	2·0			V
	Low level I/P voltage	For logic 0 level				0·8	V
	High level I/P current	Input voltage = 2·4V				−100	μA
	Low level I/P current	Input voltage = 0·4V				−220	μA
Digital outputs	High level O/P voltage	Logic 1 level	Pins 1 to 8		5·0		V
	Low level O/P voltage	Logic 0 level			0·1		V
	High level O/P current	Output voltage = 2·4V		125			μA
	Low level O/P current	Output voltage = 0·4V		−3·0			mA

Fig. 2. Specifications

220nF capacitor to stabilise the voltage reference and reduce its noise voltage. To use the internal reference for feeding into the converter, simply connect pin 10 to pin 12.

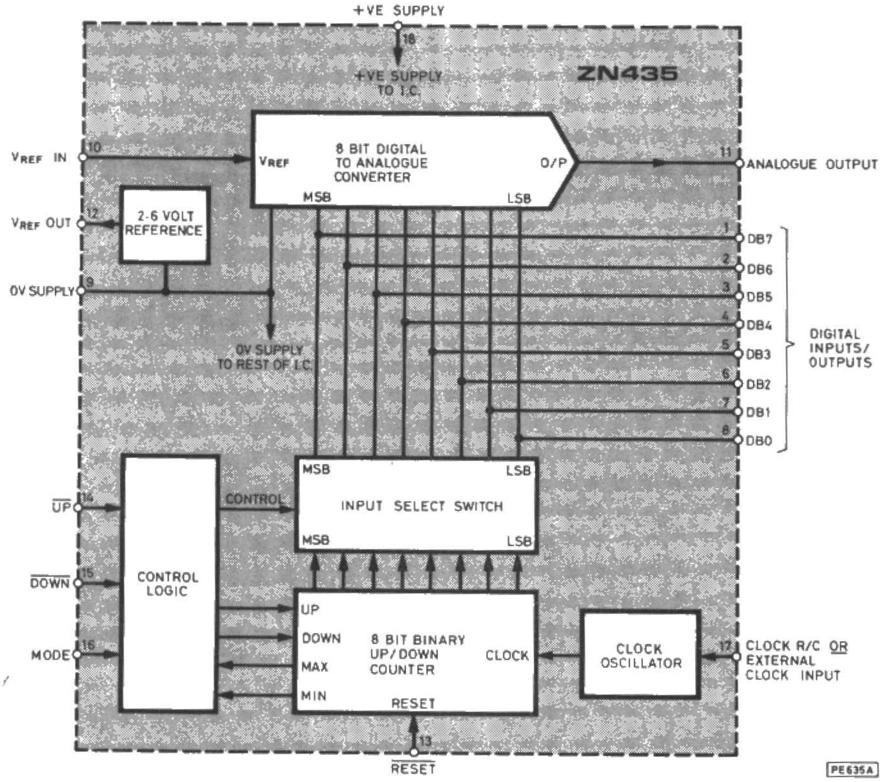
APPLICATIONS

The ZN435 can be used as a digital to analogue converter with either direct inputs, or inputs from an up/down counter, but that is rather under-using its considerable potential. With the addition of a simple comparator (an ordinary op-amp would do in many applications) a 'ramp and compare' analogue to digital converter can be made, as shown in Fig. 7. The counter is arranged to count up from zero, producing an upwards ramping voltage at the analogue output, pin 11. When this output ramp voltage exceeds the analogue input voltage, the comparator output will go high (logic 1), stopping the counter. The status output at logic 1 signals to other circuitry that the conversion is complete and the digital data output is now valid. The MODE input is held at logic 0 to prevent the counter cycling continuously if a voltage higher than V_{ref} OUT is present at the analogue input. The converter can be reset, and another conversion started, by applying a short logic 0 pulse to the reset input, which should normally be held at logic 1.

A rather more sophisticated analogue to digital converter which actually tracks the analogue input signal is shown in Fig. 8. If the input voltage rises, the digital output increases in value to follow it, and if the input decreases, the digital output also decreases to follow it; there is no requirement to start each conversion from zero.

Two LM311 comparator i.c.s are used as a window detector, IC2 being offset (by adjusting VR3 suitably) until its threshold is 10mV above that of IC3. 10mV is equivalent to one least significant bit of output code. Whenever the comparator input voltage is above the threshold of IC2, the counter will count up so that the converter output increases to match the input. Whenever the comparator input is below the threshold of IC3 the counter will count down to make the converter output decrease accordingly. If the comparator input is in the 10mV 'deadband' between IC2 turning on and IC3 turning on, the outputs of both IC2 and IC3 will be at logic 1 and the counter will be stopped. The

Fig. 3. ZN435 block diagram



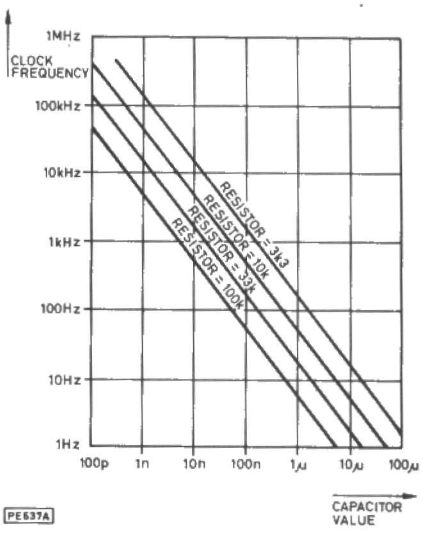


Fig. 5. Effect of R/C values on clock frequency

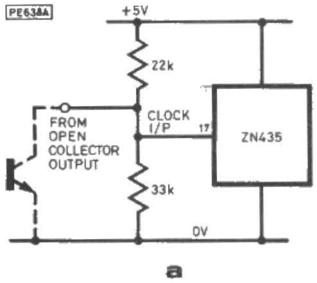
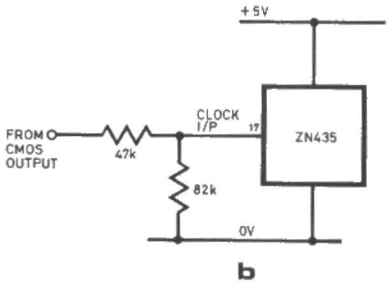


Fig. 6. Over-driving the clock input



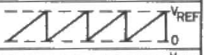
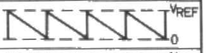
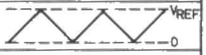
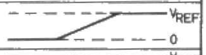
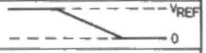
mode input is held at logic 0 to prevent continuous counting in the event of an excessively high analogue input voltage.

R1, R2, R3, VR1, and VR2 scale the input voltage of the system so that the range is −10V (for a count of zero) to +10V (for a count of 255). VR2 should be adjusted to give a count of 128 (10000000 in binary) for a 0V analogue input. (For optimum accuracy, the count should actually be 128 for a +39mV input). VR1 should be adjusted to give 255 for +10V input, and 0 for −10V input. The use of other resistor values would allow different input voltage ranges, of course.

The ZN435 is an extremely versatile device due to the availability to the 'outside world' of its various component parts. It has many applications in more specialised or unusual circuits requiring conversion between analogue and digital signals, and yet it is very straightforward to use. When operated at a very low clock frequency, it would make a superb teaching aid for analogue to digital converters in schools or colleges! The applications project this month shows yet another use for this interesting i.c.

AVAILABILITY

The Ferranti ZN435 is manufactured in two versions, the standard ZN435E, and the slightly higher specification ZN435J. The ZN435E is more than adequate for most applications, and is available from **Maplin Electronic Supplies Ltd.**

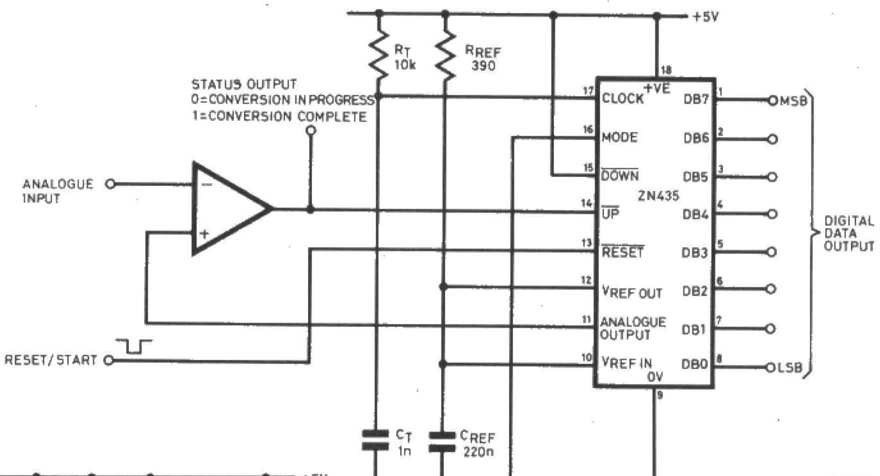
RESET PIN 13	MODE PIN 16	DOWN PIN 15	UP PIN 14	DIGITAL FUNCTION	ANALOGUE WAVEFORM (AT PIN 11)
1	1	1	1	COUNTER STOPPED	———
1	1	1	0	COUNT UP CONTINUOUSLY	
1	1	0	1	COUNT DOWN CONTINUOUSLY	
1	1	0	0	COUNT UP, REVERSE AT FULL SCALE, COUNT DOWN, REVERSE AT ZERO, ETC.	
1	0	1	1	COUNTER STOPPED	———
1	0	1	0	COUNT UP, STOP AT FULL SCALE	
1	0	0	1	COUNT DOWN, STOP AT ZERO	
X	0	0	0	DIGITAL TO ANALOGUE MODE. COUNTER OUTPUT DISABLED. COUNTER CAN STILL BE RESET BY TAKING PIN 13 LOW.	———
0	X	X	X	COUNTER RESET. DOES NOT AFFECT ANALOGUE OUTPUT IN DIGITAL TO ANALOGUE MODE.	———

N.B. X = "DON'T CARE" CONDITION–INPUT CAN BE EITHER 0 OR 1

PE636A

Fig. 4. Control of the ZN435 i.c.

Fig. 7. A "ramp and compare" analogue-to-digital converter using the Ferranti ZN435 integrated circuit. The ramp is generated by allowing the counter to count upwards from zero



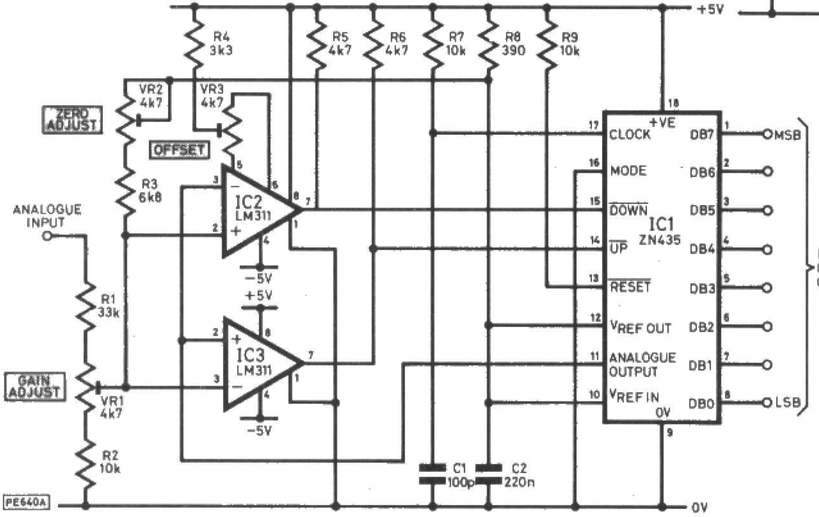


Fig. 8. A "tracking" analogue-to-digital converter using the Ferranti ZN435 D-to-A chip. This is a rather more sophisticated converter because the counter follows the input up and down, and does not have to repeatedly start from zero

AN ANALOGUE/DIGITAL WAVEFORM GENERATOR

WHEN testing microcomputers, instrumentation systems, A to D or D to A converters, and other similar systems, it is often useful to have available a variable analogue voltage, preferably of a repetitive nature, and its digital representation. Fig. 9 shows a waveform generator with such an analogue and digital output, with its Veroboard layout given in Fig. 10. Unlike Figs. 7 and 8, in this case the mode input of IC1 is tied to logic 1 to deliberately allow its counter to continue running after full-scale or zero have been reached. Switch S2 selects the output waveform required by controlling the $\overline{\text{UP}}$ and $\overline{\text{DOWN}}$ inputs. Because the counter is running continuously, it will either count up continuously, then jump to zero, then count up again, etc., giving a forward-going sawtooth waveform (position 1 of S2), or the reverse, giving a backward-going sawtooth (position 2 of S2), or it will count up, then down, then up, etc., giving a triangle wave.

The positive or negative going slope will last for 256 clock cycles; hence, the frequency of the waveform is 1/256 times the clock in the case of the sawtooth waveforms, or 1/512 times the clock, because of the two ramps required for each cycle, in the case of the triangle wave. Varying the clock frequency will obviously vary the waveform frequency, so S1, C1 to C7, R1, and VR1 arrange for a wide range of clock frequencies to be made available. This will allow *triangle* waves to be able to be generated over the range of less than 0·01Hz to greater than 1kHz, with the sawtooth waveforms being twice this frequency. The digital output, of course, will always give a binary value equivalent to the analogue voltage.

IC2 is a dual op-amp arranged to buffer the output of IC1 and add an optional offset, and variable gain. With S3 in the open position, IC2b merely amplifies the output voltage directly. The output range is therefore from 0 to +0·6V, up to 0 to +4V, depending on the setting of VR2. (The outputs of IC2 clip at +4V due to saturation effects, being so close to the supply rail.) With S3 closed, an offset is added into IC2b to give an output which ranges from ±0·3V to ±3V, again depending on the setting of VR2. If a very accurate 'zero' output is required in this offset mode, then R7 should be replaced by a 4k7 preset. IC3 is a voltage converter i.c., used to provide a −5V rail to IC2. If a negative supply is already available, then IC3 and C13 may be omitted.

In use, the circuit is largely self-explanatory. At the highest frequency setting there is some frequency non-linearity due to the threshold and parasitic effects mentioned earlier, which changes the frequency range somewhat, hence the choice of value for C7. If this still proves to be a problem, then the value of C7 should be adjusted suitably.

The analogue/digital waveform generator can provide very stable ramp and triangle waveforms with a corresponding digital code, showing yet another ususual application for the ZN435 converter i.c.

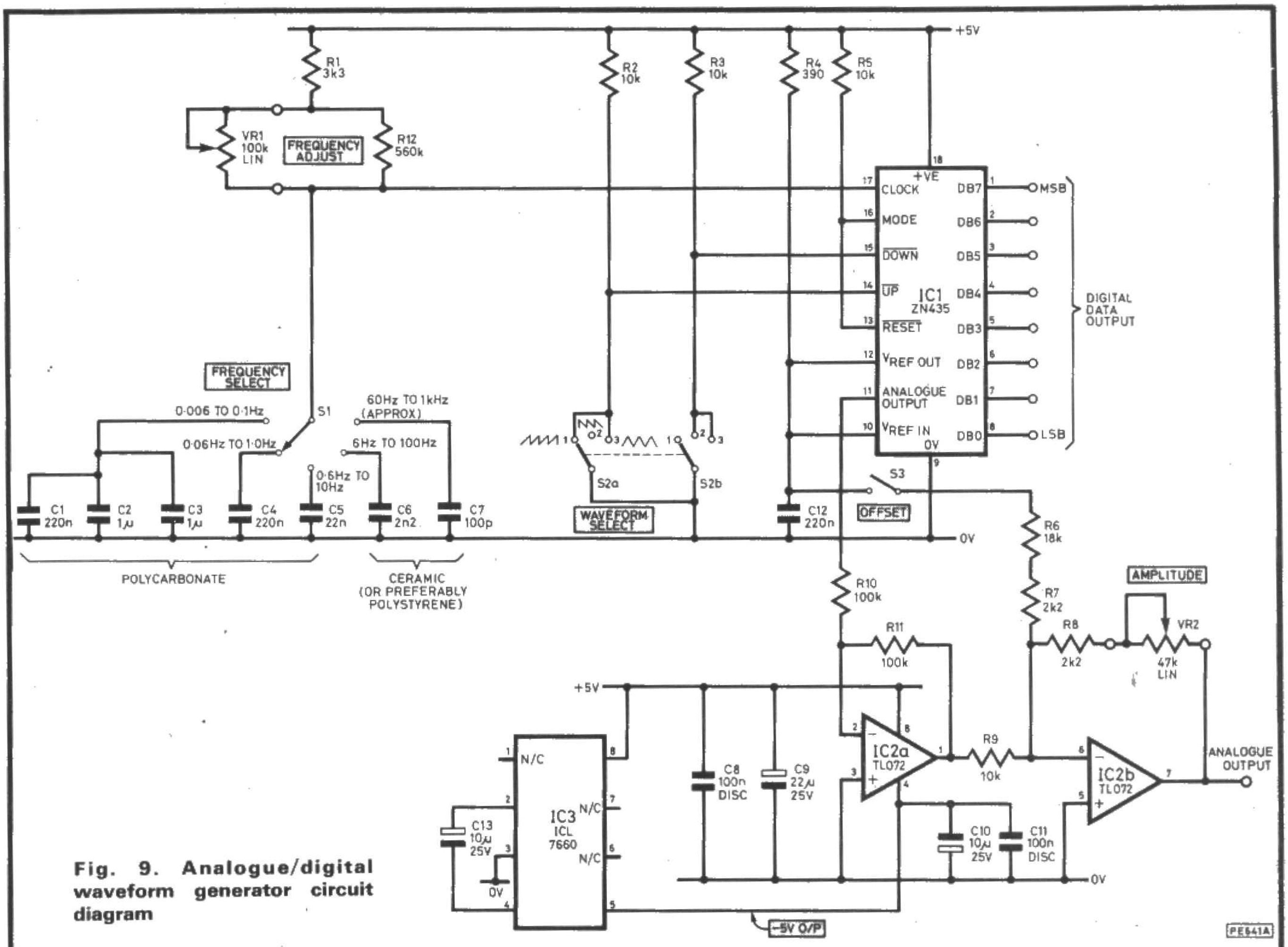


Fig. 9. Analogue/digital waveform generator circuit diagram

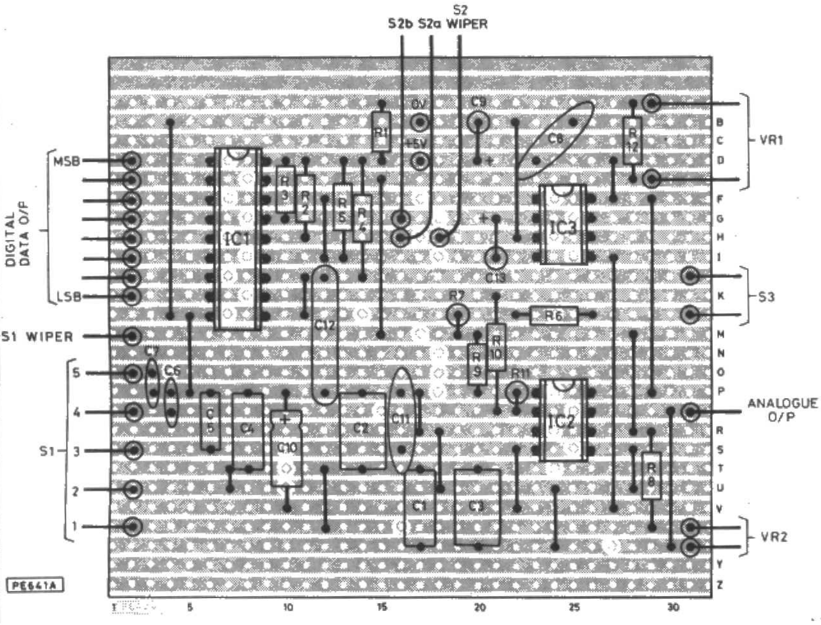
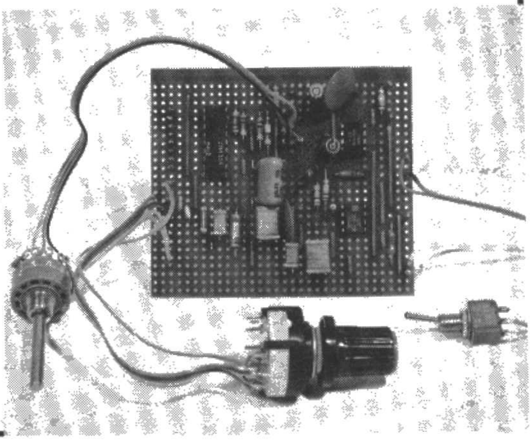
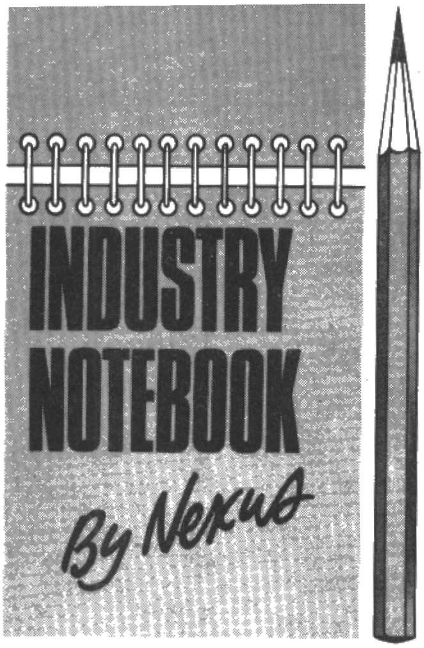


Fig. 10. Stripboard layout of the waveform generator





INDUSTRY NOTEBOOK

By Nexus

Revolutions

The history of electronics is a succession of revolutions, not only in the transition from the spark transmitter and the coherer of the turn of the century to today's solid state technology, but also in mechanical construction and assembly.

Only the truly elderly will now remember the breadboard layout and ebonite front panels of the 1920s, and the middle-aged the almost universal adoption of the metal chassis in the 1930s. These years also saw the introduction of plastic as an alternative to wood in the cabinets of domestic radios.

The great post-war revolution in assembly was the introduction of the printed circuit together with flow soldering and, later, automatic component insertion. As p.c.b.s became more complex and component density rose, so Computer-Aided-Design (CAD) became a necessity instead of a luxury.

The latest revolution, already upon us, is surface mounting of microchips and other micromin components which are automatically positioned on the p.c.b. and cemented into position prior to flow-soldering.

This form of assembly, in conjunction with multilayer p.c.b.s, allows a given circuit complexity to be achieved on a board area one-third of the size of the previous (and still current) state-of-the-art. And, when used with modern automatic placement machines, as many as 200,000 components can be mounted on 1,000 boards in one hour.

A size reduction to one-third is perhaps a conservative estimate. A new CAD system called Visula from Racal-Redac is claimed to cut p.c.b. size to as much as one-fifth using multilayer boards with ultra-fine-line routing and surface mounted components on both sides of the board. Once the board has been designed, Visula will output the manufacturing routine including the interface to automatic component placement machines.

The almost incredible power of such new design tools, manufacturing tools and, at the end of the production line, automatic test equipment is having a critical impact on employment and work practices.

Knock-on

In mass production of electronic assemblies the long rows of women assemblers hand-mounting components, hand-wiring and hand-soldering, are fast vanishing as automation takes over. The bulk of circuit design has passed from equipment manufacturers to semiconductor manufacturers who can supply off-the-shelf or custom-designed i.c. packages for almost any conceivable circuit function.

The knock-on effect continues through to outside specialist suppliers. The standard 19-inch rack and panel standing six feet high has not entirely gone but the circuitry it contained with old-style components and construction can now be accommodated in an enclosure measured in cubic inches. Buildings to house the equipment have become smaller. Hence a loss to steel manufacturers and to the construction industry.

The most basic component, copper wire, is still around in quantity but big users like British Telecom are buying less. BT has already installed 30,000km of optical fibre and has just ordered a further 23,000km at a cost of £9 million. Traditional cables are not exactly finished but the writing is on the wall. The copper in existing trunk routes can be recovered with a possible knock-on effect to third world copper producers like Zambia.

Of course there are gains as well as losses in the labour equation. There is a redistribution with, for example, the Visula p.c.b. CAD systems having taken 175 man-years of development time. But we can only guess how many thousand man-years of design effort will be saved by its users.

Surface mounting in large scale production has the advantage of a cheaper end-product for the consumer. But as the components are cemented on to the p.c.b. there is little chance of repair and the whole board becomes a throw-away item. Unskilled labour is adequate for a plug-in replacement.

Craft

Happily, once we turn away from mass production of consumer items we can still find work for the craftsman in small quantity high-value-added design and construction. An example is a seven-off order for 20W transmitters worth £260,000 to Marconi Defence Systems. At over £37,000 each they seem rather expensive. That is until you are told that they operate up in L-band and in outer space. The customer is the European Space Agency.

If successful in flight trials scheduled for early next year the Marconi TAMS (Transmit Amplifier Modules) could well become a world standard in which case further production would doubtless reduce unit-cost. Even so, such units will never be mass produced and will remain a virtually hand-crafted product.

At ground level there is still much small-batch construction. Such is the two-million-dollar contract won by Marconi Communications Systems for a 500kW transmitter for the 'Voice of America' short wave broadcasts from Greenville, North Carolina. Equipment of this size and power has to be built, not turned out on an automated assembly line.

As a generalisation the UK should concentrate on highly skilled high-value-added work and leave high volume production to those who do it most economically which, at present, is in Asia.

This view is reinforced by a survey conducted by the Ministry of International Trade and Industry in Japan. MITI's findings were that of all the significant inventions of the past 40 years the British accounted for 55 percent, the United States only 22 percent and the Japanese a paltry 5 percent. It depends on MITI's assessment of 'significant' but I believe that the general experience over this period is that we are good at innovation but comparative duffers when it comes to mass production when measured in terms of productivity. I may add, fortunately, that we are improving.

What Next?

Miniature, subminiature and microminiature describe successive generations of equipment. The new buzz-word is submicron which describes chips only one tenth the size of commercial devices in use today.

Silicon will remain in favour but researchers are keenly examining gallium arsenide as a more appropriate material for submicron technology. It has higher electron conducting power and, with the tiny dimensions envisaged, a much higher operating speed.

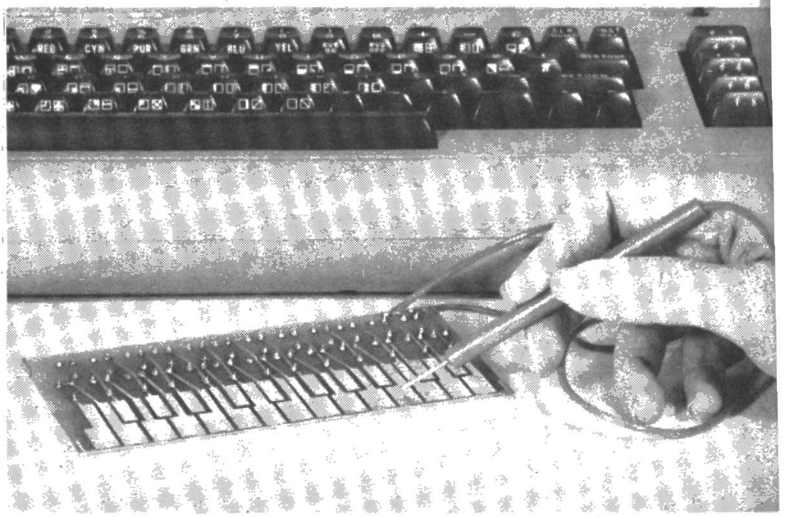
Glasgow University's Ultra Small Structure Group has a £500,000 grant from the Science and Engineering Research Council for investigation of such devices which could become available commercially in a few years time. The research programme is in co-operation with BT and Plessey.

The World

The expected though sudden emergence of new leadership in the Kremlin is another example of how external events can influence prospects. The dismal performance of the economy of the Soviet Union is now said to be top priority but if improvement is to be made then the solution can come only from the West as is openly acknowledged by the now enlightened Chinese.

The British mission, headed by Lord Young, returned from China in mid-March full of enthusiasm for increased trade. The Soviets may not follow the Chinese lead but they can't afford to fall further behind in living standards and consumer shortages while the capitalist economies surge ahead and the Chinese are catching up. So we may expect new export prospects for western technology in the civil sector. After all, enhanced mutually beneficial trade may be the best guarantee of lasting peace.

CBM 64 MUSIC KEYBOARD



R.A.PENFOLD

WHILE many home computers have quite complex and versatile sound generator circuits which are well suited to music making, the lack of a conventional musical keyboard can render even the best of home computers of little value to someone who wishes to use the unit as an ordinary instrument. Music either has to be programmed and then played back automatically, or the computer has to be played via the typewriter style keyboard.

This problem is not insurmountable, and a conventional or stylus keyboard can easily be added to many home computers. In this article we will be dealing with the Commodore 64, an obvious choice due to its highly advanced sound generator chip, the 6581 SID (sound interface device). The Commodore 64 probably has the most advanced sound generator circuit of any current home computer. It has, unremarkably, three tone-channels, but has a choice of four waveforms per channel (triangle, sawtooth, variable pulse, and noise). The noise output has a definite pitch which can be varied like any of the other waveforms, and it is quite possible to play music using a noise waveform. Another feature is proper ADSR envelope shaping (although there are admittedly only fifteen different volume levels), and even such things as ring modulation and various types of filtering can be provided.

KEYBOARD INTERFACING

Two methods of interfacing a keyboard to the machine will be considered here. One approach is to interface the keyboard by way of a paddle input on one of the joystick ports. Here only a stylus type keyboard is interfaced using this method, but precisely the same technique could easily be applied to a "proper" keyboard if desired. The other method of interfacing enables a synthesiser keyboard to be interfaced to the computer's user port. The CV output of the synthesiser (which must be of the standard 1 volt per octave law) is connected to the user port via what is really just a straightforward analogue to digital converter. Apart from enabling the sound generator to be played from the keyboard, a useful aspect of interfacing the computer to a synthesiser is that the audio output from the computer can be mixed with and used to augment the normal output of the synthesiser. This is especially useful with a simple single VCO synthesiser, but also greatly enhances a twin VCO type.

STYLUS KEYBOARD

The Commodore 64 has two games paddle inputs on each joystick port, but there are in fact only two inputs in total since the paddle inputs of joystick port 1 are merely connected in parallel with those of joystick port 2. These inputs are in fact provided by the 6581 SID, and are not the usual voltage sensitive analogue inputs. They are simple resistance sensitive types using a CR timing network and a counter circuit. In effect the CR timing circuit is used in a monostable multivibrator, and the counter operates for the duration of the output pulse.The higher the value of the timing resistor the longer the pulse length, and the higher the count registered by the counter. The two counters can be read at two registers of the 6581, and as they are 8-bit types the returned value is in the normal 0 to 255 range.

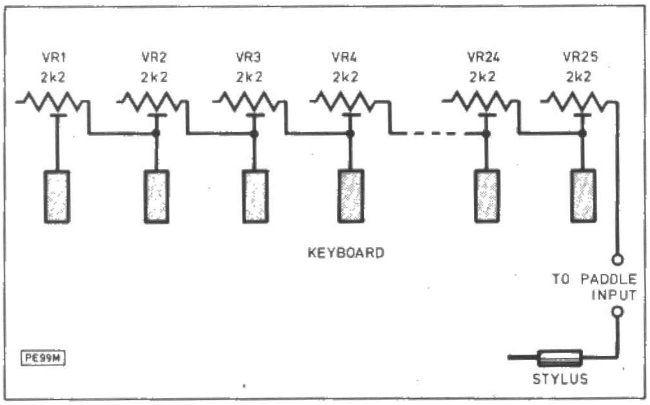


Fig. 1. Circuit of the simple stylus keyboard

COMPONENTS . . .

STYLUS KEYBOARD

Potentiometers
VR1 to VR25 2k2 0·1W horizontal presets (25 off)

Miscellaneous
Printed circuit board, available from the *PE PCB Service*, order code 506–02, 9-way D socket, test prod for stylus, wire, solder, etc.

In this application all we have to do is to arrange the keyboard so that each note provides a suitable resistance at one of the paddle inputs. A software routine is then used to convert the numbers returned from the 6581 register into the correct notes, or to silence the sound generator when the keyboard is not activated and a reading of 255 is returned. The paddle inputs have a full scale value of around 400k or so, which works out a little under 2k per division. In practice the precise full scale value will vary somewhat from one machine to another, and the linearity is not very good either. In order to obtain reliable results it is therefore necessary to use a series of preset resistors rather than fixed types so that they can be trimmed to give the required values.

The circuit of the stylus keyboard is shown in Fig. 1. For the sake of clarity only six preset resistors in the chain of 25 are shown. A series of 25 presets gives a range of two complete octaves including semitones, but with over 200 different values available from a paddle input and the wide range of notes available from the 6581 SID (about 8 octaves) a much wider compass could be covered if desired by using more presets and a suitably extended keyboard. It would obviously be quite straightforward to modify the circuit to suit a normal keyboard, with s.p.s.t. contacts being used to switch in the appropriate number of presets for each note.

CONSTRUCTION

Refer to Fig. 2 for details of the printed circuit board for the stylus keyboard. Construction is very simple with just the 25 presets to be soldered into place, the connection to the stylus to be made, and the two connections to be taken to one of the controller ports (either port will do). The stylus can be an inexpensive test prod of the type sold as replacements for multimeters, or something like a jack plug could be used. Probably many constructors will be able to find something suitable in their spares box.

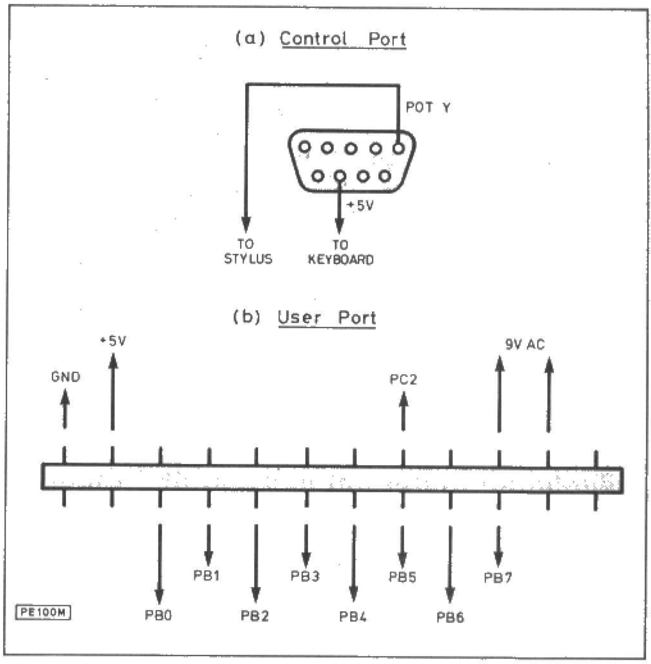


Fig. 3. Connection details for (a) the controller port and (b) the user port

The connections to the controller port are made by way of a piece of two way cable and a nine way D-type connector. Provided this cable is no more than about 1 metre or so long it should not be necessary to use a screened lead, but if a screened lead is used its outer braiding should connect to the "5V" terminal of the port, with the inner conductor carrying the connection to the "POT Y" terminal. Connection details for the controller port are given in Fig. 3(a).

The printed circuit board is arranged to provide two octaves from E to E, but this could obviously be modified to suit individual requirements by those who are making their own board and, as explained earlier, a greater range of notes can be produced if more presets and "keys" are used.

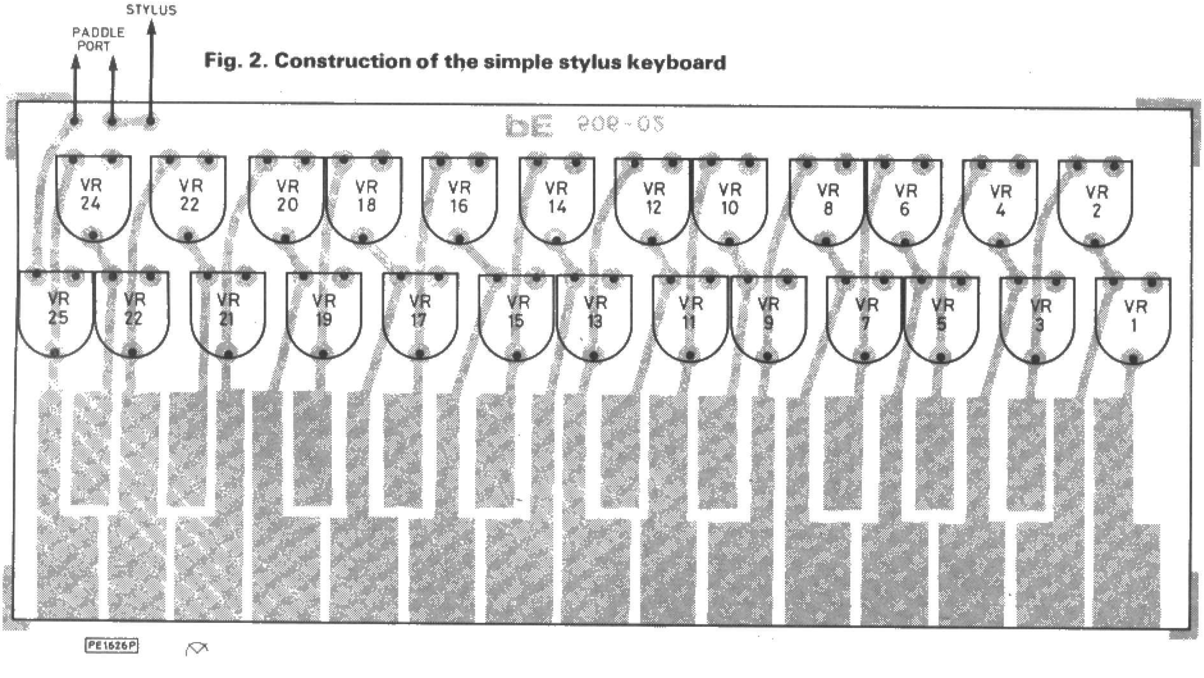


Fig. 2. Construction of the simple stylus keyboard

SETTING UP

In order to facilitate setting up of the presets the following two line program should be entered into the computer.

```
10 PRINT PEEK(54298)
20 GOTO 10
```

This merely reads the paddle port continuously, printing the returned values down the left hand side of the screen. Select the highest note using the stylus, and then adjust VR25 for a steady reading of 1. Then move down a note and adjust VR24 for a value of 2. Then move down another note and adjust VR23 for a reading of 3. Continue this process until all the presets have been adjusted in sequence, with a value of 25 being obtained for VR1. Note that the presets must be adjusted in sequence, starting with VR25 and working downwards to VR1.

SOFTWARE

The "POT Y" input is read at address 54298, and the suggested software routine in the first listing takes the returned value and converts it into the appropriate two values to give the correct note from channel 1 of the sound generator. Refer to the Commodore 64 manual for a full list of register values for the musical notes available. The program uses the "look-up table" method, where the returned value points to the position of the note values in a table. If you try writing your own software bear in mind that a value of 1 is produced by the highest note, incrementing by one per note to 25 for the lowest note, and the note values must be arranged in the look-up table (the DATA statements) accordingly.

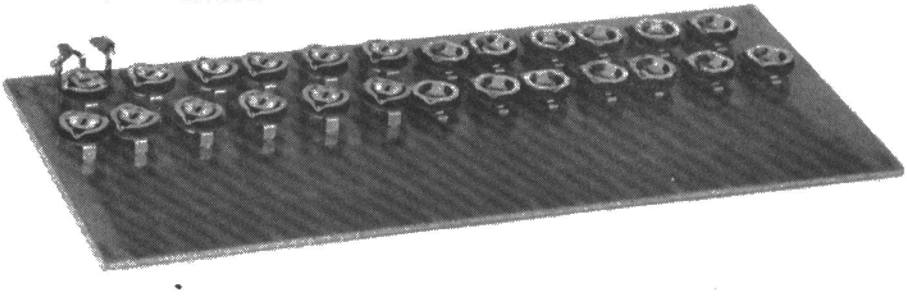
The program must do more than just write the correct values to the frequency control registers, and the required waveform must be selected by POKEing the appropriate value to Voice Control Register 1 at address 54276. In this case a value of 33 is used, and a triangle waveform is obtained, but any of the available waveforms can be obtained by using the appropriate value. Another function of the program, and an important one, is to provide gating of the sound generator. In other words, sound must only be produced when the stylus is on the keyboard, and not at other times. This is in fact not strictly true, since the sound generator has ADSR envelope shaping, and the sound may therefore continue after the gate period has ended for a time dictated by the selected "release" period. The gating is obtained by continuously POKEing a value of 33 to the voice control register when a valid note value is returned from the paddle port. At other times a value of 32 is written to the voice control register. This takes bit 0 of the register low and ends the gate period.

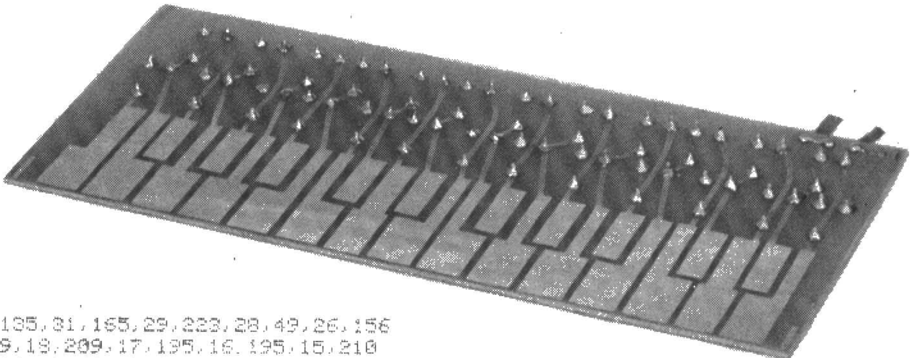
The envelope shape for channel 1 of the sound generator is controlled by the two registers at addresses 54277 and 54278. A full description of the 6581, which is a highly complex device, really goes well beyond the scope of this article. However, the *Commodore 64 Programmers Reference Guide* which is published by Commodore gives full data on this device, and programming details. This should be considered essential reading for anyone who intends to use the Commodore 64 with either of the keyboard systems described in this article. Facilities such as filtering and ring modulation have not been included in the program, but are something that could easily be added once you have mastered the basics of 6581 programming.

SYNTH INTERFACE

The synthesiser interface uses the analogue to digital converter circuit of Fig. 4 to convert the control voltage output of the synthesiser to a value that can be read via the user port. The control voltage output of a synthesiser, provided it is a standard one volt per octave type, is equal to a certain potential per note. In fact it increments by a little under 100 millivolts per note. This is very convenient for the current application since we can arrange things so that a value of 1 is obtained for the first note, 2 for the second, and so on.

The converter circuit is very straightforward, and is based on a ZN449 eight bit successive approximation device. In fact only six bits are used here, giving a maximum range of over five octaves, which is adequate in practice, and is likely to be far more than the synthesiser's keyboard is capable of providing. There are more accurate and expensive versions of the ZN449 (namely the ZN448 and ZN447), but as the converter is effectively a 6-bit type in this application there would be no advantage in using one of the more accurate devices.





Program listing for the stylus keyboard

```
   1 REM STYLUS INTERFACE PROGRAM
   5 DIM T(25,1)
   9 GOSUB 1000
  10 POKE 54277,3
  20 POKE 54278,168
  30 POKE 54296,15
  60 N=PEEK(54298)
  70 IF N > 25 THEN GOTO 60
 100 L=T(N,0):H=T(N,1)
 110 POKE 54273,L
 120 POKE 54272,H
 125 IF N < 26 THEN POKE 54276,33
 130 N = PEEK(54298)
 140 IF N < 26 THEN 130
 150 POKE 54276,32
 160 GOTO 60
1000 FOR V = 1 TO 25
1010 READ T(V,0),T(V,1)
1020 NEXT V
1030 RETURN
2000 DATA 42,62,39,223,37,162,35,134,33,135,31,165,29,223,28,49,26,156
2010 DATA 25,30,23,181,22,96,21,31,19,239,18,209,17,195,16,195,15,210
2020 DATA 14,239,14,24,13,78,12,143,11,218,11,48,10,143
```

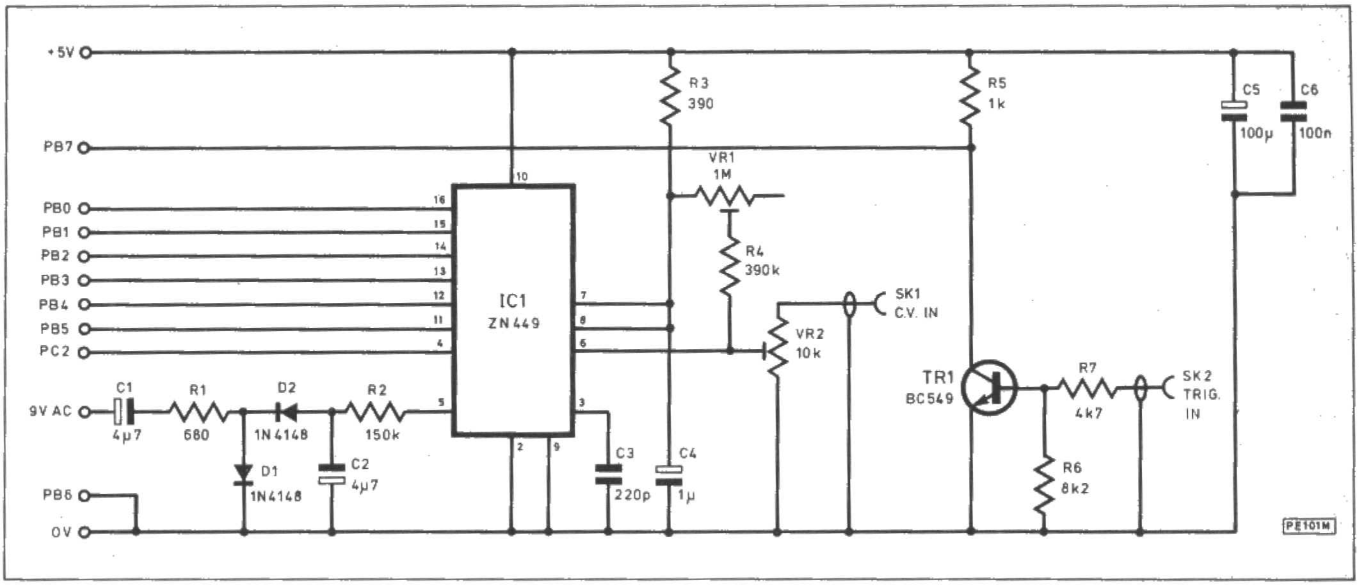


Fig. 4. The synthesiser interface circuit diagram

A negative supply is required for the discrete "tail" resistor (R2) in the comparator stage of the converter, and although the user port does not provide a negative supply it is quite easy to generate one from one of the 9 volt a.c. outputs that are available. This is achieved using the simple rectifier and smoothing circuit based on D1 and D2.

The ZN449 has a built-in clock oscillator which requires just one external capacitor to set its operating frequency. In this circuit C3 is the clock oscillator's timing capacitor and its value of 220p sets the operating frequency at about 400kHz. This gives a conversion time of approximately 22·5 microseconds, which is more than adequate for this application. The digital to analogue converter section of IC1 has a built-in 2·55 volt reference voltage source, but this requires discrete load resistor R3 and decoupling capacitor C4.

As the converter has a full scale input voltage of nominally 2·55 volts, but a synthesiser covering the maximum five-and-a-bit octave range would give a maximum potential of just over 5 volts, the input voltage must be attenuated somewhat. This attenuation is provided by VR2, and this preset control is adjusted to bring the full scale input voltage of the circuit to precisely the correct level. The ZN449 requires a discrete zero offset circuit in order to give good accuracy at low input voltages, and the necessary positive bias is provided by VR1 and R4. VR1 is adjusted to optimise accuracy.

To produce a conversion a negative pulse must be supplied to the "start conversion" input at pin 4 of IC1. In this case the PC2 handshake line is used to provide the pulse, and this gives a negative pulse of about 1µs in duration immediately following any read or write operation to the eight data lines of the user port. If a continuous stream of readings are taken the start conversion pulses are produced automatically after each reading is taken, but where necessary a dummy read or write operation can be used to initiate a conversion. When using BASIC the relative slowness of this language ensures that a conversion is always completed before a reading is taken. However, when using machine code a delay of at least 25µs should be allowed between readings to ensure that the converter always has time to produce a valid reading.

Transistor TR1 is an inverter stage which processes the gate output signal of the synthesiser to give a negative gate pulse that will reliably drive the PB7 input of the user port. Lines PB0 to PB5 are fed with the six (used) outputs of the analogue to digital converter, and the unused data line PB6 is simply connected to earth. A returned value of 128 or

COMPONENTS . . .

SYNTH INTERFACE

Resistors

R1	680
R2	150k
R3	390
R4	390k
R5	1k
R6	8k2
R7	4k7

All ¼W 5% carbon

Potentiometers

VR1	1M 0·1W horizontal preset
VR2	10k 0·1W horizontal preset

Capacitors

C1,C2	4µ7 63V radial elect. (2 off)
C3	220p ceramic plate
C4	1µ 63V radial elect.
C5	100µ 10V radial elect.
C6	100n ceramic

Semiconductors

IC1	ZN449
TR1	BC549
D1,2	1N4148 (2 off)

Miscellaneous

SK1,SK2 standard jack sockets (2 off)
2 by 12 way 0·156 inch pitch edge connector, small plastic or metal case, printed circuit board, available from the *PE PCB Service*, order code 506–03, 18 pin d.i.l. i.c. holder, ribbon cable, wire, solder, etc.

more thus indicates that no key is depressed, when a key is operated a value of 1 to 63 is obtained, indicating which key has been operated. Of course, in most cases the keyboard will cover a range of no more than three octaves, giving a maximum note value of 37 or less.

CONSTRUCTION

All the components are accommodated by a small and easily constructed printed circuit board, as shown in Fig. 5. Connections to the user port of the computer are carried via a piece of 12-way ribbon cable about 0·5 to 1 metre long. This has its free end fitted with a 0·15 inch pitch, 2 by 12 way edge connector. Details of the connections to this are shown in Fig. 3(b). As the edge connector is unlikely to have a polarising key it essential to make sure that it is connected to the computer the right way round, and it is advisable to clearly label the "top" and "bottom" edges of the connector.

The completed board is mounted in a small plastic or metal case after first wiring it to SK1 and SK2 which are mounted on the front panel. An exit hole for the ribbon cable must be cut or filed in the rear of the case unless a suitable gap can be found.

IN USE

Sockets SK1 and SK2 respectively connect to the CV OUT and GATE or TRIG OUT sockets of the synthesiser by way of the usual screened jack leads. Start with VR1 and VR2 set at roughly mid point and then enter the simple two line test program that follows.

```
10 PRINT PEEK(56577)
20 goto 10
```

Depressing a key of the synthesiser should produce a returned value of between 1 and 63. If the synthesiser has (say) 37 keys, operate the highest key and adjust VR2 to produce a stable reading of 37. Then operate the lowest key. This may give a steady reading of 1, and in this case no further adjustment of the unit is likely to be needed, with each key returning the correct value. If a reading other than 1 is obtained, trim VR1 to produce the correct reading. Then operate the highest key again and, if necessary, adjust VR2 for the correct reading again. This process should be continued until the interface tracks properly over the full range of notes covered by the synthesiser.

Program listing for the synthesiser interface

```
   1 REM SYNTH INTERFACE PROGRAM
   5 DIM T(37,1)
   8 GOSUB 1000
  10 POKE 54277,0
  20 POKE 54278,168
  30 POKE 54296,15
  60 N=PEEK(56577)
  70 IF N > 37 THEN GOTO 60
  90 N = PEEK(56577)
 100 L=T(N,0):H=T(N,1)
 110 POKE 54273,L
 120 POKE 54272,H
 125 IF N < 38 THEN POKE 54276,33
 130 N = PEEK(56577)
 140 IF N < 38 THEN 130
 150 POKE 54276,32
 160 GOTO 60
1000 FOR V = 1 TO 37
1010 READ T(V,0),T(V,1)
1020 NEXT V
1030 RETURN
2000 DATA 8,97,8,225,9,104,9,247,10,143,11,48,11,218,12,143,13,78,14,24
2010 DATA 14,239,15,210,16,195,17,195,18,209,19,239,21,31,22,96,23,181
2020 DATA 25,30,26,156,28,49,29,223,31,165,33,135,35,134,37,162,39,223
2030 DATA 42,62,44,193,47,107,50,60,53,57,56,99,59,190,63,75,67,15
```

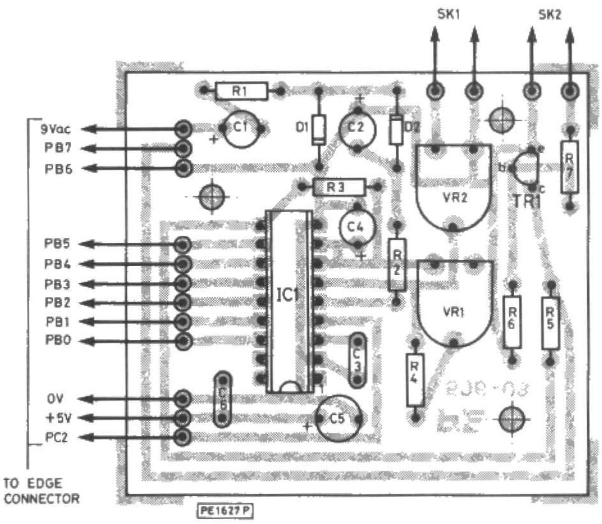
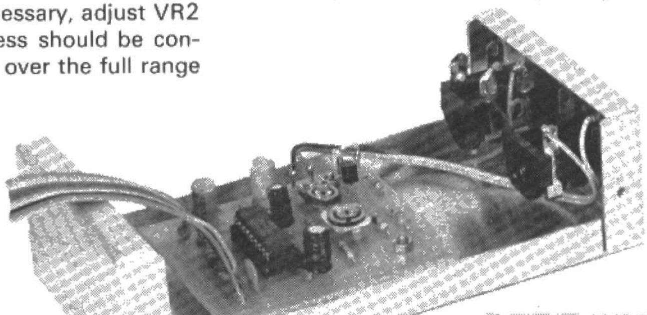


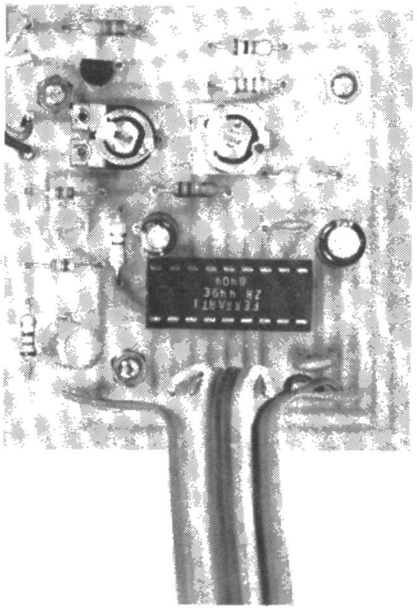
Fig. 5. Construction of the interface p.c.b.

SOFTWARE

Although it is possible to play faster using a proper keyboard than it is when using a stylus type, a BASIC program seems to give a perfectly adequate speed for use with the synthesiser interface, and it is not essential to resort to a machine code program. The second listing is suitable, and this is a slightly revised version of the stylus keyboard listing described earlier. The main differences are that the keyboard values are obtained from a different address (56577), and that a range of 37 notes from C to C are covered.

As was the case with the stylus keyboard listing, the program is only intended as a starting point, and refinements such as switching up or down one or two octaves, waveform selection, etc. could be incorporated. With this type of project there is almost unlimited scope for anyone wishing to develop sophisticated supporting software. ★





SPACEWATCH

By Dr. PATRICK MOORE O.B.E.

QUASARS

In July last year I wrote about the great quasar problem. Are these enigmatical objects really as remote and as luminous as their spectral red shifts indicate, or are they much closer, so that the red shifts are misleading?

Almost all astronomers favour the first view, but there are some dissentients, notably Sir Fred Hoyle in Britain and Dr. Halton Arp in the United States. Arp has long maintained that quasars are associated with relatively nearby galaxies, so that their red shifts are not 'cosmological', though even in this case the quasars would still be millions of light-years away.

Dr. Arp has published lists of aligned galaxies and quasars which have different red shifts. He has now announced the detection of a third quasar close to the galaxy NGC 3842. Two quasars in this area were already known, and the third also lies within 73 seconds of arc of the galaxy. He considers that this is too improbable to be a coincidence unless there is a real association.

However, there remains the fact that if quasars were ejected from galaxies, some of them ought to be moving toward us, so that the shifts in the lines in their spectra would be to the blue or short-wave end—and up to now no blue-shifted quazar has been found. Until, or unless, this happens, it is likely that most authorities will continue to believe that the red shifts really are reliable guides to the quasar distances.

Much has been heard recently about the possibility of collisions between the Earth and solid bodies from space. Of course many meteorite falls have been seen, but there have been no trustworthy reports of any human death due to such an event. However, within the last few months there have been a couple of "near misses". On 30 September 1984 a meteorite—or a fragment of a meteorite—landed only a dozen feet away from two sunbathers in Perth, in Australia, while on 10 December a meteorite crashed into a postbox at Claxton, in Georgia, less than 150 feet away from the nearest observer. Both meteorites were recovered and analysed; both are of the type known as chondrites.

PLUTO

Pluto is often termed "the outermost planet". True, its mean distance from the Sun is much greater than that of Neptune, but its comparatively eccentric orbit means that when near perihelion it is closer-in. Perihelion is due in 1989, so that between 1979 and 1999 Pluto is moving within the orbit of Neptune—though there is no fear of a collision, because Pluto's orbit is also tilted at the unusually sharp angle (for a planet) of 17 degrees.

Pluto was discovered in 1930 by Clyde Tombaugh, then a young student but now one of America's most senior and respected astronomers. The discovery was made at the Lowell Observatory, Flagstaff, and was the result of a deliberate hunt. Percival Lowell, who had died in 1916, had worked out the possible position of a new planet from small irregularities in the movements of Neptune and Uranus; Pluto turned up not very far from the predicted place. Yet it was a puzzle from the start. We now know it to be smaller than the Moon, with a mass so low that it could not possibly produce any measurable perturbations in the motions of giants such as Neptune and Uranus. Either Lowell's fairly accurate position was a sheer fluke, or else the real "Planet X" remains to be discovered.

In 1977 it was found that Pluto is not a solitary wanderer in space; it is attended by a satellite, now called Charon, with a diameter about one-third that of Pluto itself. Moreover, the situation is unique inasmuch as Charon has a revolution period of 6·3 days—and this is the same as that of Pluto's axial rotation, so that to an observer on Pluto, Charon would appear motionless in the sky.

It has been predicted that at some time around the mid-1980s there would be mutual occultations of Pluto by Charon and vice versa, and that these might be detectable by a drop in the total magnitude—remembering that in normal telescopes Pluto and Charon appear as a single point; to see them separately requires electronic equipment used with a giant telescope. It now seems that these predicted phenomena have started. The first event was noted by R. Binzel and E. Tedesco, of the Jet Propulsion Laboratory, on 16 January, and the second was in February, noted on the 17th by Binzel and on the 20th by D. Tholen of the University of Hawaii.

The change in brightness is very slight, amounting to no more than 0.04 of a magnitude, but it is quite definite. The telescopes used were the reflectors at Palomar, the McDonald Observatory in Texas, and the 2·2-metre instrument on Mauna Kea.

There seems no reasonable doubt that mutual occultations are responsible, and it

THE SKY THIS MONTH

Both the really brilliant planets are on view this month, though not in the evenings. Venus is a morning object in the Eastern sky; it reaches its greatest brilliancy (magnitude −4·2) on May 9. It will then be less than 30 per cent illuminated, and any small telescope—or even good binoculars—will show its crescent form. It will not reach dichotomy, or half-phase, until mid-June, but it will then be further away from us, and the apparent diameter will be less—which more than compensates for the extra amount of sunlit hemisphere turned in our direction.

Jupiter, in Capricornus, is visible for several hours in the South-East before dawn. Saturn, in Libra, reaches opposition on May 15 and so is above the horizon throughout the hours of darkness; its magnitude is 0·2, only very slightly fainter than Vega or Capella, and the rings are wide open.

Of the other planets, Mars is being lost in the evening twilight, and as its apparent diameter is now less than 4 seconds of arc no telescope will show much surface detail, while Mercury is well South of the celestial equator and is not likely to be seen with the naked eye.

The Moon was full on 4 May, and will be new on 19 May. There will be a partial eclipse of the Sun on the 19th, when 84 per cent of the bright disk will be hidden, but the eclipse is not visible from anywhere in Britain.

Orion has now disappeared, but the other famous 'guide', Ursa Major, is almost overhead; almost everyone can recognize the seven stars making up the pattern nicknamed the Plough or the Big Dipper. Following round the curved line of the Bear leads to Arcturus, the lovely orange star which is actually the brightest star visible from Britain apart from Sirius; it is one of only four stars which are above magnitude zero—the other three being Sirius, Canopus and Alpha Centauri.

Continuing the line leads to Spica in Virgo, which is a white first-magnitude star; the rest of Virgo is made up of a somewhat Y-shaped pattern of stars, one of which (Gamma Virginis), at the base of the Y, is a well-known binary with almost equal components. It used to be very wide and easy, but it is closing up, and by the end of the century it will appear single except with large telescopes.

Below Spica is the well-marked quadrilateral making up Corvus, the Crow. Leo, the Lion, is dropping in the West, while the brilliant blue Vega is gaining altitude in the East. Later in the night Scorpius, the Scorpion, will be visible, low in the South-East, led by the red supergiant Antares. Scorpius is a magnificent constellation, but it is too far South to be properly appreciated from Britain, and the prominent "sting" barely rises even from South England.

also seems that the eccentricity of Charon's orbit is very low. It is thought that even more marked events will be seen in future months, and they will be of great importance, as they will lead to better determinations of the sizes and masses of the two bodies.

FREE ORBIT

But can Pluto be regarded as a true planet? It does not seem to fit into the general pattern of the Solar System, and there are good grounds for demoting it from its planetary status, particularly in view of the 1977 discovery of what seems to be a large asteroid, Chiron (not to be confused with Charon) which spends most of its time between the orbits of Saturn and Uranus.

In 1936 R. A. Lyttleton suggested that Pluto used to be a satellite of Neptune, and broke free to move off in an independent path. Perhaps significantly, Neptune's remaining large satellite, Triton, has a retrograde orbit, and seems to be larger and more massive than Pluto; it is thought to have an icy surface, possibly with oceans of liquid nitrogen or methane. According to Lyttleton's theory, interactions between Pluto and Triton led to the expulsion of Pluto from the Neptunian system, and the forcing of Triton into a retrograde orbit.

Unfortunately there are serious mathematical objections, and the discovery of Charon has made them worse, so that most astronomers regard the theory as untenable. A new suggestion has now come from W. B. McKinnon of Washington. This time Pluto and Triton are assumed to have had original orbits round the Sun, and Triton was captured by Neptune, with Pluto not involved at all.

This too seems to have drawbacks, as the capture of Triton would involve a very special set of circumstances, but it cannot be ruled out. On the other hand, it may well be that there are many asteroid-sized bodies in the far reaches of the Solar System, in which case Pluto may be merely the brightest of them—though admittedly this does not explain why Triton, alone among large satellites, has an orbital motion opposite to that of the axial spin of its primary planet.

Perhaps Planet X, if it exists, will throw new light on the problem. Unfortunately none of the probes now moving outward from the Sun will go anywhere near Pluto, but *Voyager 2* is scheduled to by-pass Neptune and Triton in 1989, so we may have new information then.

HALLEY UPDATE

Halley's Comet is brightening steadily, and has now been seen visually with large telescopes, but it will be lost during June, when it is in conjunction with the Sun. Regular observations by amateur observers are unlikely to begin before August, when the magnitude will rise to about 13 and the comet will be a morning object in Orion.

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13 reels unused. Tandberg T.G.B. sound tapes 1,800 ft. long play, 7" reels. Offers plus postage. L. T. Hill, 14 Rothesay Terrace, Bedlington, Northumberland.

EPSON FX80 printer as new. Paper interface lead manual cover in carton. £350. Mahen, 241 Norbury Crescent, London SW16 4LF. Tel: 01-764 0839.

STRAIN gauge amplifier type 605A. High grain amp in diecast box, switched gain, 12 volts d.c. £3 inc. p&p. Mr. Wyer, 2 St. Edmund Place, Dundee, Scotland.

GAMES boards Z80 lots TTL 2716 ram £14. Two each Z80 sound 8255 £22, 2708 20p. Mr. D. J. Lakey, Orchard Cottage, Draycott Road, Blockley, Glos. GL56 9DY.

WANTED UK101s in working order uncased unexpanded preferred reasonable price paid. P. B. Unstead, Threeways, Hambro Hill, Rayleigh, Essex. Tel: 0268 743113.

FOR sale: volumes 1 & 2 of J. Atkinson's book: 'Telephony' (Pitman Publishing Ltd.) £50 including p&p. Mohammad Ammar Alsalka, PO Box 12579, Damascus, Syria.

48K TRS–80 III, 1-disk, high-res, board, thermal printer, CGP-115 plotter—software + manuals. Home/business system. £1500 o.n.o. Nigel Crook, Stoney Lane, Ambleside, Cumbria LA22 9AZ. Tel: 0966 33441 (after 6pm).

WANTED RS232 interface with documentation for ZX81. Price negotiable. Mr. P. Feetenby, 6 Tewin Close, St. Albans, Herts. AL4 9XL. Tel: 0727 38563.

DETAILS to convert Grundig super colour A2102 C.T.V. for R.G.B. input required. Any help appreciated. Joseph Conroy, 2 Annalee Park, Butlers Bridge, Co. Cavan, Rep. of Ireland.

74 LS783 and 2764, £4 each. £35/10. 6809E £3.50 each. £30/10. Small quantity. First come, first served. Nil Spiers, 114 Greenway, Tunbridge Wells, Kent TN2 3JN.

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PE BAZAAR JUNE '85

BBC Micro Forum...

David Whitfield MA MSc CEng MIEE

IN RESPONSE to reader enquiries, I shall be bending the column's rules slightly this month by starting with a "longish" listing. This is an interrupt-driven routine for last month's numeric keypad. Then, as promised last month, a real time clock for connection to the user port will be presented.

KEYPAD DRIVER ROUTINE

The keyboard test program given last month has a number of drawbacks in practical use. The major snag is that any program using the keypad must include the software to set up the user port, and must then test the keypad for key depressions whenever any user input is expected. This all becomes extremely tedious, especially if the user is to be allowed to use *either* the micro's keyboard *or* the numeric keypad. What we really want is for user programs to be unaware of whether, for example, the "5" key has been pressed on the keyboard or keypad; and preferably to be unaware that the extra keypad is fitted at all.

Having said what we want to be able to do, the next step is to formulate a strategy. In general, the steps we need to follow are described as follows:

Set up:

(a) Configure the keypad unit to signal the user VIA whenever a key is pressed.

(b) Install an interrupt service routine in the micro to handle interrupts from the user VIA.

(c) Identify this user interrupt service routine to the MOS.

(d) Configure the user VIA to interrupt the micro whenever a key is pressed.

Then:

(e) Whenever a user interrupt occurs, and the service routine is called by the MOS, check whether the interrupt came from the keypad. If so, identify the key pressed and insert the corresponding ASCII code(s) into the keyboard input buffer; if not, pass the interrupt back to the MOS.

Now, provided that the interrupt service routine is located so that it does not affect the normal loading and running of programs, the keypad will behave as if it is an integral part of the standard keyboard. So much for the theory, but how do we achieve any or all of this in practice?

HIDING PLACE

The only change required to the keypad circuit given last month is to add a link between pins 14 and 4 on the user port, i.e. connect the Data Available signal to CB2. This extra link satisfies (a) above; all of the other requirements involve software. First, however, we need to find somewhere to 'hide' the interrupt software. This is not usually too much of a problem because the lower part of the micro's memory (i.e. below PAGE) has a number of reserved areas, and we can usually find one of these spare. Memory pages which are candidates for locating the keypad software are given in Table 1. In a cassette machine, there is a further area available between 0D00 and 0D9E; this is normally reserved for NMI handling, but NMIs are only used by the disc interface.

In a disc-based machine which does not use the RS423 port, for example, page A (i.e. the 256 bytes starting at 0A00) will be unused, and is suitable for storing the keypad routine. The actual selection of the space to be used will rather depend on your micro's expansion state, and the facilities which you wish to use at the same time as the keypad. Listing 1 uses the page starting at 0A00, but this may be altered simply by changing the value in line 100.

Once the program in Listing 1 has been typed in, save a copy *before* running it; machine code interrupt programs with bugs in them have a nasty habit of completely crashing the system! When you run the program, an assembler listing will be produced. If the program produces no errors when run, the keypad will be active, and you can carry on and use the micro as if it had always been fitted with a keypad. To deactivate the keypad, the easiest way is to press BREAK, which will restore the initial state of the user IRQ vector (IRQ2V). Alternatively, restore the original value of IRQ2V which the program stores in the two-byte area starting at "vector". For those interested in the workings of the routine, a summary is given in Table 2; the voluminous comments in the original listing have been stripped off in the interests of economy of space.

As mentioned last month, the keypad could be re-programmed so that the keys have special meanings other than their engraved numbers. This involves changing/extending the code between lines 450 and 540 to insert the required character string (corresponding to the key pressed) into the keyboard input buffer, instead of a single ASCII value. Remember, however, that the string should not cause the keyboard input buffer to overflow (it is only 32 characters long). My own favourite use of the keypad is to re-program the keys for filing system commands. Any suggestions for novel applications are always welcome at *"BBC Micro Forum Letters"*.

```
 10 IRB=&FE60
 20 DDRB=&FE62
 30 PCR=&FE6C
 40 IntFlag=&FE6D
 50 IntEnab=&FE6E
 60 IRQ2V=&206
 70 OSBYTE=&FFF4
 80 KEYBUFF=0
 90 INSERT=&8A
100 vector=&A00
110 FOR A=0 TO3 STEP3
120   P%=vector+2
130   [OPT A
140   .setup SEI
150   LDA IRQ2V
160   STA vector
170   LDA IRQ2V+1
180   STA vector+1
190   LDA #int MOD256
200   STA IRQ2V
210   LDA #int DIV256
220   STA IRQ2V+1
230   LDA #0
240   STA DDRB
250   LDA PCR
260   AND #&0F
270   ORA #&40
280   STA PCR
290   LDA #&88
300   STA IntEnab
310   CLI:RTS
320   .int
330   LDA &FC
340   PHA:TXA:PHA
350   TYA:PHA
360   LDA IntFlag
370   ROL A
380   BCS VIAint
390   ROR A
400   JMP exit
410   .VIAint
420   ROR A
430   AND #&08
440   BEQ exit
450   LDA IRB
460   AND #&0F
470   ADC #48
480   CMP #58
490   BMI dec
500   ADC #06
510   .dec  TAY
520   LDA #INSERT
530   LDX #KEYBUFF
540   JSR OSBYTE
550   .exit
560   PLA:TAY:PLA
570   TAX:PLA
580   STA &FC
590   JMP (vector)
600   ] NEXT A
610 CALL setup
620 END
```

Listing 1. Machine code keypad routine

REAL TIME CLOCK

Because of the *"Welcome"* software readers will be aware that the BBC Micro includes some basic timing facilities. If watched for any length of time, however, it is clear that this software "clock" is not absolutely accurate, particularly when discs are in use. In practice, the TIME variable is an elapsed time counter, based on the system VIA, which is started when the micro is switched on, and then updated every 10ms. The count is affected by the disc interface because this uses non-maskable interrupts which delay the response to IRQ in-

Lines	Actions
10-100	Define the symbols
140-220	Identify interrupt routine to MOS, but remember the original handler
230-310	Configure the user VIA for interrupts
320-440	Identify keypad interrupts
450-520	Convert key code to ASCII
530-540	Insert code into keyboard buffer
550-590	Exit via original MOS routine
610	Activate interrupt handler

Table 2. Program Structure

terrupts. The other problem, in addition to accuracy, is that the software clock is reset every time the micro is switched on.

The real-time clock to be described overcomes these problems affecting the micro's TIME facility because it is a hardware rather than software clock. It consists of a special purpose i.c., similar in many respects to a digital watch, and features a backup battery to maintain the time even when the micro is switched off. The completed unit can be built for around £15.

The circuit for the complete real time clock is shown in Fig. 1. At the heart of the unit is the MM58174 clock i.c. (also available from RS as 304–548). The i.c. uses a low cost 32·768kHz crystal for timekeeping, with fine time adjustment provided by the trimmer capacitor. The signal produced by the oscillator stage is passed to a series of dividers, which in turn produce tenths, units and tens of seconds, units and tens of minutes, units and tens of hours, units and tens of days, units and tens of months. In addition, the divider chain also keeps track of the leap year cycle and the day of the week. A series of 16 registers serve to hold the time information and to control the operation of the clock, as shown in Table 3.

The nominal 3·6 volt 100mAh p.c.b. battery is a widely available low cost item (e.g. RS 591–477). When fully charged, the battery has enough capacity to keep the clock going for two to three months after the micro is switched off, or after the unit is disconnected. Switch-over to the low power standby mode of operation is automatically performed by the i.c. when the supply voltage falls below 4·0 volts. The battery is topped up by being trickle charged whenever power is available from the micro.

The negative write strobe is required by the i.c. only when setting up the clock registers initially. Therefore, and because I/O lines on the user VIA are limited, steering logic has been used to allow manual switching between the read and write modes. Although not the most elegant approach, this does avoid much complicated latching. The manual switch-over is only necessary during initial setting up, and thereafter all operations involve only reading from the clock. An alternative approach to this problem will be described in a future column (when a clock for connection to the 1MHz bus will be described), but for the present this simple interface will be quite adequate for most applications. The single transistor connected to the negative chip select line provides an active logic 0 source, and allows the i.c. to function correctly in standby mode.

The prototype unit was built on a small piece of veroboard and connected to the micro via the usual 20-way cable, with a plug and socket arrangement at each end. The clock and logic i.c.s are static-sensitive, and so were fitted in d.i.l. sockets. The link shown on the circuit should only be made after the i.c.s have been installed in their sockets, but with the unit disconnected from the micro. The link also allows the standby current to be measured, and should be less than approximately 50μA. No other special constructional considerations apply. The fine adjustment of time allowed by the trimmer capacitor allows the clock to be speeded up by reducing the capacitance (vanes open on the trimmer). Conversely, increasing the capacitance will slow down the clock. The effect of adjusting the trimmer will, however, take a number of days to become noticeable; start with it at the half-meshed position.

SETTING UP

When the unit is powered up, it is necessary to enter the correct time into the registers, and then start the clock running. In practice the process is a little more complex than as just described.

First the clock must be set in normal mode (write a 0 to register 0), the clock stopped (write 0 to register 14), and the interrupt latch cleared (write a 0 to register 15, and then read this same register back three times). The seconds, minutes, hours, days and months counters are then each loaded with the start time data. The year status register (13) should be set to 8 for a leap year, 4 for the 2nd year, 2 for the 3rd year, and 1 for the 4th year in the leap year cycle. Finally, the day of the week register (10) counts continuously from 1 to 7, and should be set to an appropriate value (e.g. Monday = 1).

In order to write a value to a register, the mode switch must be set to write, the data to be entered must be set up on the 4-bit data bus, the address in Table 3 must be set up on the 4-bit address bus, and a negative write strobe given. All registers are set up in the same way, and the clock is then started at the required instant by writing a logic 1 to register 14. Once the clock has been started, the mode switch should be returned to the read position. Data may then be read back from the time registers by setting up the register address and applying a negative read strobe. Should the clock be read while the registers are being updated, a code of '1111' will be returned to indicate that the time must be re-read.

A final note of warning, programs written in BASIC will *not* run fast enough to allow a continuous display of time *and* allow the clock to keep accurate time; something which you may otherwise find out the hard way (I did!).

NEXT MONTH

NEXT MONTH *BBC Forum* will include software for setting up and reading the real-time clock, and will be starting to look at the analogue port.

Fig. 1. Real Time Clock Unit

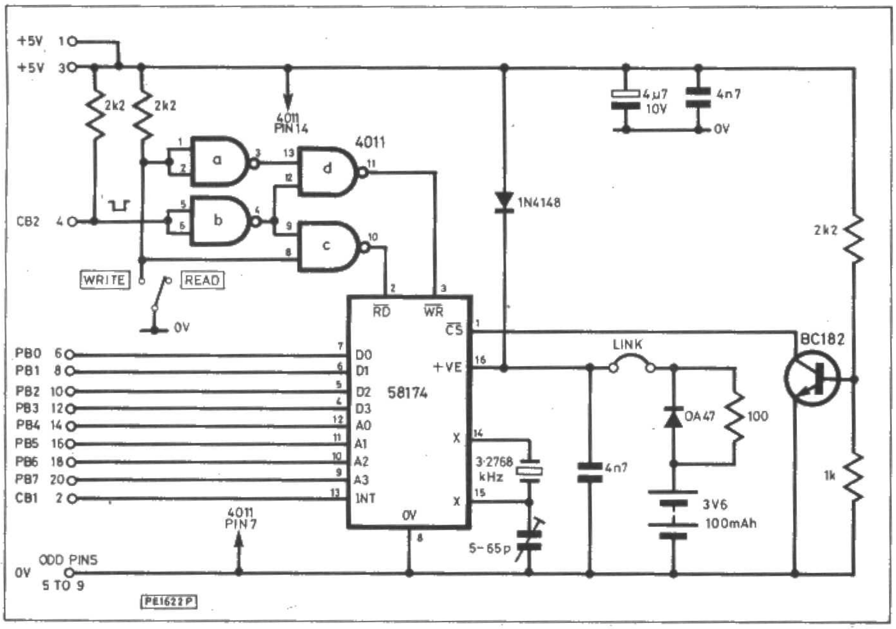


Table 1. Memory Assignments

0A00-0AFF	Cassette/RS423 i/p buffer
0B00-0BFF	Function key definitions
0C00-0CFF	User-defined characters

Table 3. RTC Registers

Register	Contents	Mode
0	Test Only	W
1	Secs/10	R
2	Seconds	R
3	Secs * 10	R
4	Minutes	R/W
5	Mins * 10	R/W
6	Hours	R/W
7	Hours * 10	R/W
8	Days	R/W
9	Days * 10	R/W
A	Day of Week	R/W
B	Months	R/W
C	Months * 10	R/W
D	Year	W
E	Stop/Start	W
F	Int/Status	R/W

speech 64 review

R.A.PENFOLD

THE Currah Speech 64 is a fairly sophisticated speech synthesiser for the Commodore 64 computer (a version for the Spectrum is also available incidentally). It connects to the cartridge port rather than, as one might have expected, the user port, and apart from the short lead and plug that carry the audio output the unit looks just like an ordinary program cartridge. In fact the Speech 64 does include some firmware to aid the production of the required phrases, and it is for this reason that it has to interface to the computer via the cartridge port instead of the user port. The lead and five-pin DIN plug connect to the audio input on the audio/video socket of the computer so that the speech, like the ordinary sound output of the computer, is reproduced through the sound channel of the television set. If the computer is used with a monitor it could be awkward to connect everything properly, but provided the monitor has an audio channel which reproduces the normal sound output of the computer properly, it should be possible to obtain satisfactory results.

In Operation

With the Speech 64 unit connected and the computer switched on, the command INIT has to be used before the unit is brought into action. With a few exceptions such as RUN/STOP and RESTORE, pressing a key results in the name of the key being spoken through the sound channel. This is useful as the unit uses the allophone system of speech synthesis, and it enables the user to quickly become familiar with many of the sounds that are available. For those who are not familiar with the allophone system it should perhaps be explained that the synthesiser has a vocabulary of basic sounds rather than whole words. The required phrases therefore have to be built up by stringing together suitable allophones. Pressing letter keys gives what are in most cases single allophones, but when the keys such as RETURN and the SPACE bar are operated a sequence of allophones to produce the whole word is obtained, demonstrating the way in which perfectly intelligible words can be produced from a series of basic sounds.

Compared to the whole word approach the allophone system has the drawback of slightly lower speech quality and it is generally a little slower and more difficult to use. In truth a well designed and sophisticated speech synthesiser based on the allophone system can, nevertheless, be quite easy to use, and can offer surprisingly good speech quality. It would be fair to say that the Speech 64 unit is in this category. The advantage of the allophone method is that it gives an unlimited vocabulary instead of typically only about one or two hundred words for whole word synthesisers.

Strengths and Weaknesses

Running through the keyboard shows up the strengths and weaknesses of the synthesiser as far as accuracy of pronunciation is concerned, and the only peculiarity is the American zee rather than zed for the Z-key. The Speech 64 is built in the UK. After initial familiarisation the keyvoices can become a little irksome, but they can be switched off and on using KOFF and KON. There are two different voice pitches available, and the higher of these is the default setting. KON 0 selects the lower pitch, which is substantially lower and gives the unit what are effectively two completely different voices; something which could be useful in practical applications. In a lighter vein, the computer can be made to hold a conversation with itself. The lower voice, although perhaps the less natural sounding one, seems to give marginally clearer speech. For instance, the difference between the N and M sounds is more apparent with the lower pitched voice.

With simple allophone speech synthesisers it can take quite a lot of effort to produce even quite short phrases due to the need to continually look up allophone addresses. With the Speech 64 this is unnecessary, and with the aid of the SAY instruction it is virtually just a matter of typing in the required words in their normal English form. Unfortunately, it is not quite that simple as letters are pronounced different ways in different words, and some manipulation of words is sometimes required in order to obtain the desired result. For instance, the line:—

```
SAY "HELLO ROBERT PENFOLD"
```

would give reasonable results on the first and last words, but would interpret the word ROBERT as two syllables, ROBE and RT. This can be corrected by using an apostrophe (which gives a very short pause) to break up the word in the correct way. In other words:—

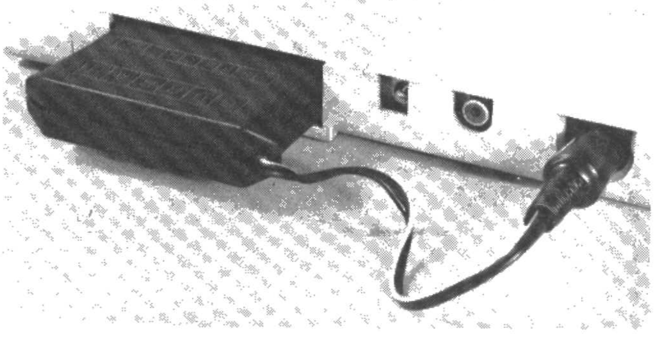
```
SAY "HELLO ROB'ERT PENFOLD"
```

would give the correct pronunciation. In other cases purposely misspelling words can give the correct pronunciation.

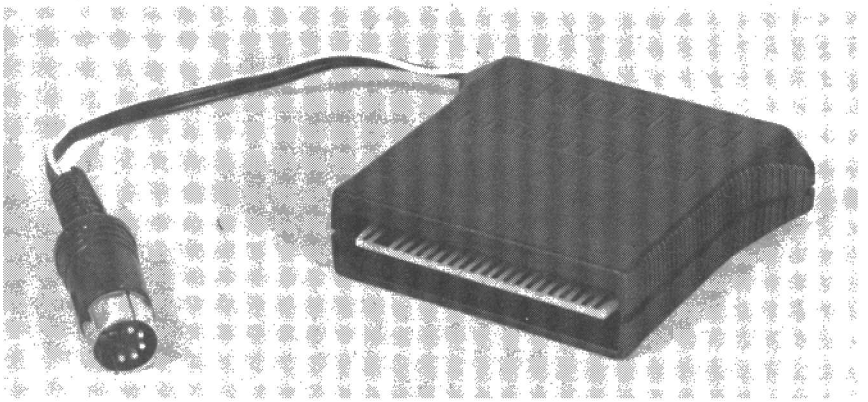
Intonation

It is possible to use the allophones directly, and as they are selected using one, two, or three letter mnemonics rather than numbers this is still a fairly easy way of generating phrases. The code letters have been chosen to relate to their sounds in a very obvious way (wh as in which for example). The code letter or letters are placed in square brackets to indicate that the direct mode is in use, and two or three letter codes are placed in brackets to indicate that they form a single code. For the user who has gained some experience with the unit the direct allophone mode is probably the one that will give the best results.

A common and often justified criticism of speech synthesisers, particularly the allophone type, is that of a very mechanical sound due to a lack of any pitch modulation in the voice. In the direct allophone mode the Speech 64 unit can in fact produce intonation, and a much more realistic voice sound. This works in a very simple way with codes in upper case letters being intonated (which in practice really just means raised slightly in pitch), and lower case codes being reproduced nor-



mally. With careful use this can give surprisingly good and realistic results. As a simple example of how intonation can be used to good effect, words are often spoken with an initial pitch that is higher than the final pitch, especially when they occur at the beginning of a sentence. The word hello could therefore be intonated in this manner:—
SAY "¼HE(11)(oo)·"



The Currah Speech 64

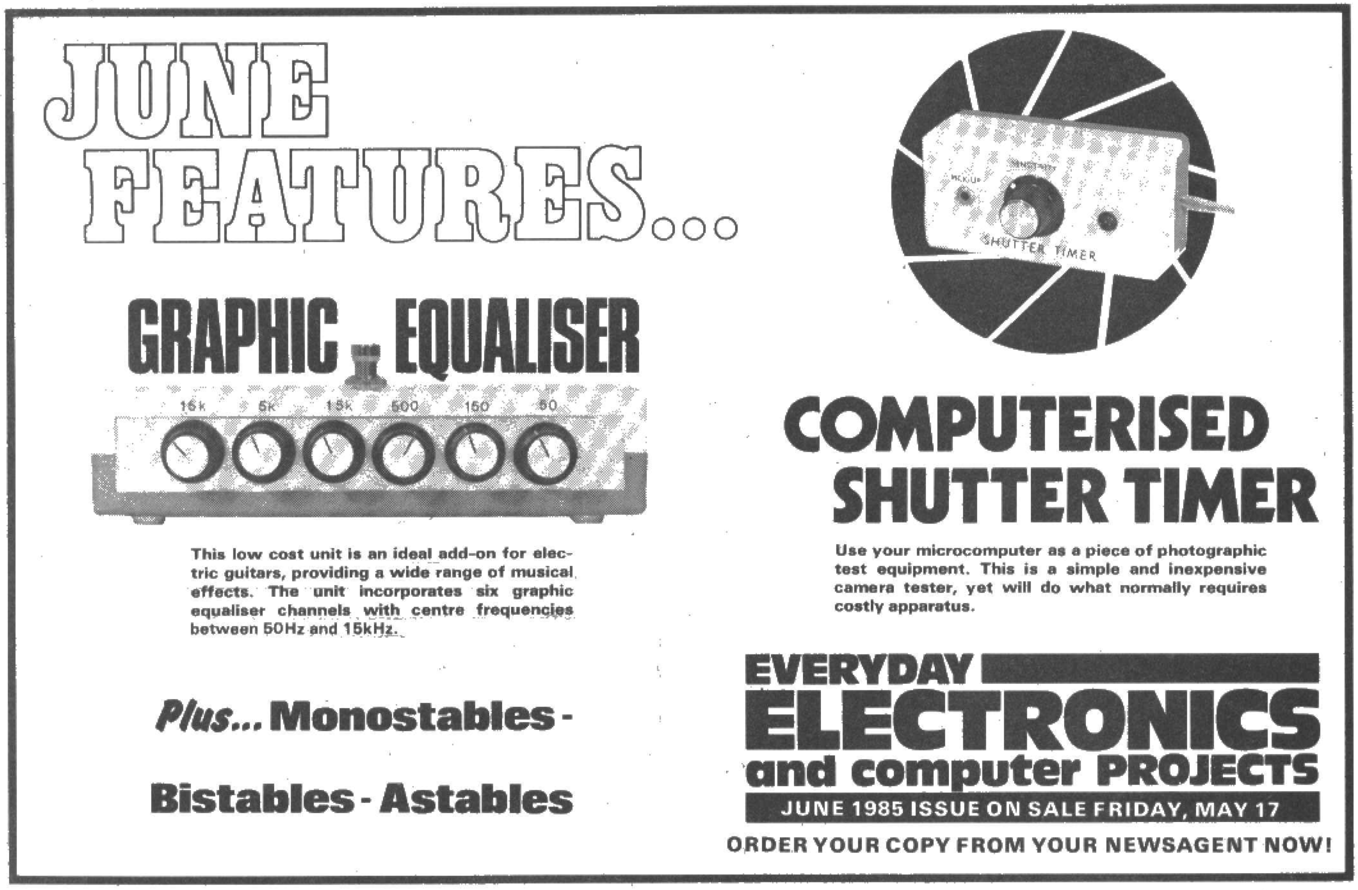
Due to the Commodore 64's twin character set, which does not include lower case characters in the normal set, some care has to be taken when using intonation as mistakes are easily made, but one soon gets the hang of things and it is well worth making the effort to master this aspect of the unit. The improvement in realism can be quite marked. Intonation is available on both the high and low pitched voices.

A speech buffer can hold up to 256 allophones so that programs are not halted while phrases are reproduced, but accidentally overflowing the buffer must be avoided as this would result in phrases being lost. 256 allophones represents about 30 seconds worth of speech and should be more than adequate. However, a variable called SP% contains the number of free bytes in the buffer, and can be brought into action in situations where there is a danger of the buffer overflowing.

The Speech 64 can be operated from machine code if required, but this is a relatively difficult way of doing things as the allophones have to be accessed via their address numbers. The unit is provided with a small 16-page booklet which covers more advanced topics such as machine code programming of the unit as well as the basics. It also includes a Speaking Clock program which demonstrates the capabilities of the synthesiser. Bearing in mind the ease with which the unit can be used the modest sized manual is more than adequate, and is both well written and easy to understand.

Conclusion

The Currah Speech 64 is certainly an impressive product, and although it may seem expensive when compared to a simple home constructed speech synthesiser based on the SPO256 (which is presumably the chip on which the unit is based) it is really in a different league. The built-in firmware, two voices, and intonation capability enable speech of quite reasonable quality to be easily generated. No real flaws or even minor ones came to light when testing the unit. ★



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OP-AMP SIGN CHANGER

THIS useful application circuit is little used by the electronics experimenter, but has plenty of applications in signal processing at low frequencies.

In Fig. 1, with the arm of VR1 at position 'B', the non-inverting input is grounded causing the circuit to act as normal inverting amplifier with unity gain. This will give an output where V2 = −V1. If the arm is now moved to position 'A' then V1 is applied to both ends of R1. Also as no signal current flows through the op-amp, there can be no current in R2, thus V2 = +V1.

With the arm in the mid position, V1/2 is applied to both inputs and with good common mode rejection obtained with modern op-amps, V2 = 0. This set up can be very useful as a phase inverting gain control stage and can be calibrated with a scale such as: +high, 0, −high.

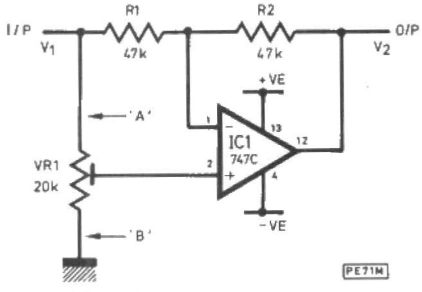

Fig. 1.

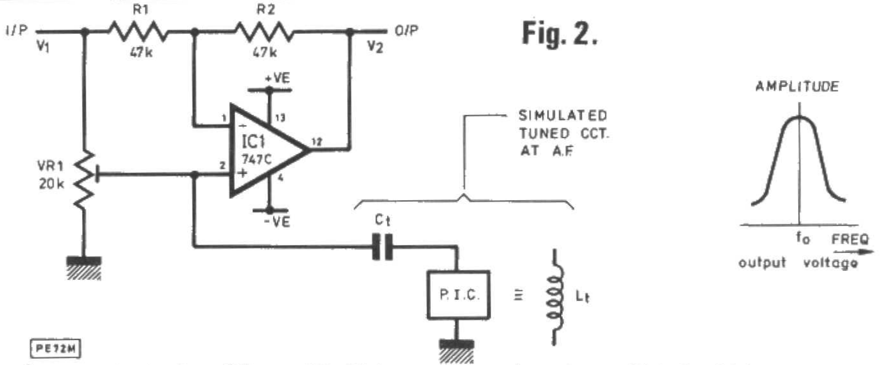

Fig. 2.

In Fig. 2 a similar circuit is being used to simulate parallel tuned circuit response. With VR1 set to reject the input signal, the source impedance feeding L_t, C_t is equal to 10K. This allows the filter to be variably tuned and also cascaded. Other applications for Positive Impedance Converters (PICs) were featured in Practical Electronics, June 1981.

A. B. Bradshaw,
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Digital Delay & Sound Sampler

WITH COMPUTER INTERFACE

John M.H. Becker **Part 1**

THE project described here consists of a 512K integral memory block arranged as a 64K × 8-bit sound sampler. With the associated compander and filter network, an equivalent resolution of 15-bit sampling is achieved, allowing a 15kHz bandwidth. For ordinary musical use, the delay available is constantly variable from 4ms to 8s and for special effects it can be extended up to one and a quarter minutes.

Delay selection is normally by a special wow-less circuit. Panel controls enable the unit to be used for echo, reverb, double tracking, phasing, flanging, chorusing, vibrato, amongst others, plus looped signal storage. It can also be linked to a computer in place of the internal memory, enabling a wide variety of sound sampling and modification parameters to be program controlled. An example of a simple control program will be given later.

DELAYS

Over the years there have been a variety of methods used to provide echo and reverb effects but the coming of bucket brigade devices has greatly enriched the variety of these effects by allowing a readily variable delay. By now BBDs must be common knowledge, but as a quick recap, in them there are many storage stages, 1536 in the recently introduced TDA1097. The first stage repeatedly samples the analogue level of the signal applied. As each charge is stored so the previous charges are all moved on by one place. At the output they emerge in sequence at roughly the same levels as they went in, and at a rate variable by changing the transfer clocking frequency.

This method is excellent for short delays, and its beauty is the simplicity of the associated control circuitry. The inherent drawback though, is that each time the charge is transferred from stage to stage, a very slight deterioration occurs. Up to several hundred milliseconds, this is largely insignificant, and indeed in many units, delays of even 1s can be achieved by cascading several of the low noise TDA1097s together. For much longer delays though a digital sampling unit is essential, and increasingly practical with the continuing miniaturisation of memory devices.

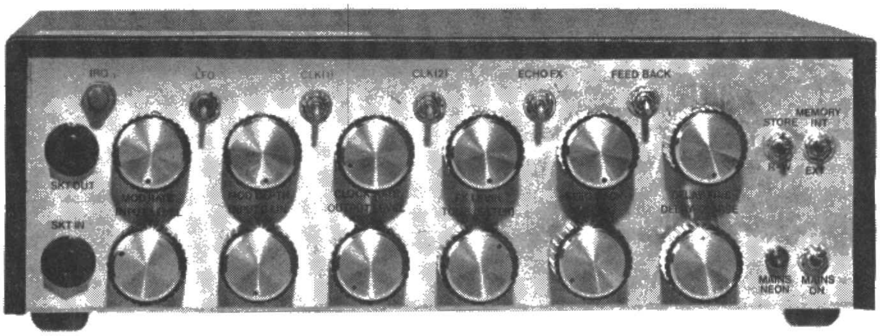
DIGITAL DELAY UNITS

Whereas in an analogue unit many transfer conversions take place, with digital units only two conversions are needed irrespective of the number of stages. In a simple unit a sample is taken of the voltage level of a signal at a particular point in time. This voltage is converted to an equivalent number which is stored in a known memory area. Subsequently the number is retrieved from memory and converted back to a voltage again. For as long as the number is in memory it is available at any time for reconversion, and so theoretically the delay between sampling and reading back can be infinite. In this way deterioration can only occur twice, at the analogue to digital, and the digital to analogue conversions, irrespective of the delay time.

A TO D CONVERSION

In broad terms, in a digital delay unit, the first thing to consider is the analogue to digital conversion. The maximum range of output numbers available is finite, and is usually limited to the range 0 to 255. The signal presented must therefore not exceed that range. The A to D process is not instantaneous so the unit must be told when to do its conversion, and as we may not want the result immediately, it must be stored temporarily, and the device told not to do any more conversions until the first has been used.

When we are ready for it, it has to be transferred to a known location in the long term memory so that we can find it at a later time. This means that an address location numbering system is needed. In the compact memory chips used here the address data required is in a column and row grid, so the address has to be split into two sections, one for each. The memory handles these two sub addresses at separate times, so it needs to be told which section is which, when to deal with it, and whether it is to store or read data at the specified address.



Having stored the data at one location, we will usually want to read back data from an earlier location. So we need to change the address, and its row and column data. The memory of course has only one set of address lines, consequently we need a set of gates so that when the Write address is needed, the Read address is shut off, and vice versa.

When the stored data has been found the next consideration is that the memory input and output lines are mutually joined to the A to D and to the D to A converters. The timing sequence must therefore tell the D to A not to listen to data being written to the memory, and the A to D to ignore data being read back. When permitted, the D to A takes the numerical data from the memory and converts it back to a voltage level equivalent to that originally presented to the A to D at the start of the timing cycle now concluded.

At the start of the next cycle another bit of analogue data must be sampled, and another previously stored bit read back, so the Write and the Read addresses must both be updated. This process continues indefinitely and in this unit with 64K (bytes) of memory, 65536 different address locations are available (in computer terms 1K of memory actually means 1024 locations, so 64 × 1024=65536). Eventually of course all addresses will have been used up, at which point the counter resets to the first address and continues through again, overwriting the previous data.

So far so good, we are successfully sampling an analogue signal, storing it, reading back an earlier bit, and reconverting it to a signal. However, none of this process is instantaneous, and a delay occurs between sampling the first bit of data, and the next. In the meantime the input signal has probably changed its level and when sampled, digitalised and reconverted to analogue, a noticeable step in the output analogue signal will occur, representing the two different sampling points. Fortunately this can be readily filtered so that the step variations are smoothed out and the resulting reconstituted signal is usually barely discernible from the original, providing the sampling rate is fast enough.

After filtering, the signal can be fed to the usual amplifier. In a practical circuit, a number of other things can be done as well, such as feeding the signal back upon itself, or mixing it with the original, and varying the rate at which the sampling occurs by modulating the sampling control with another oscillator. Let's now look at this idea in detail. Fig. 1. shows the schematic block diagram.

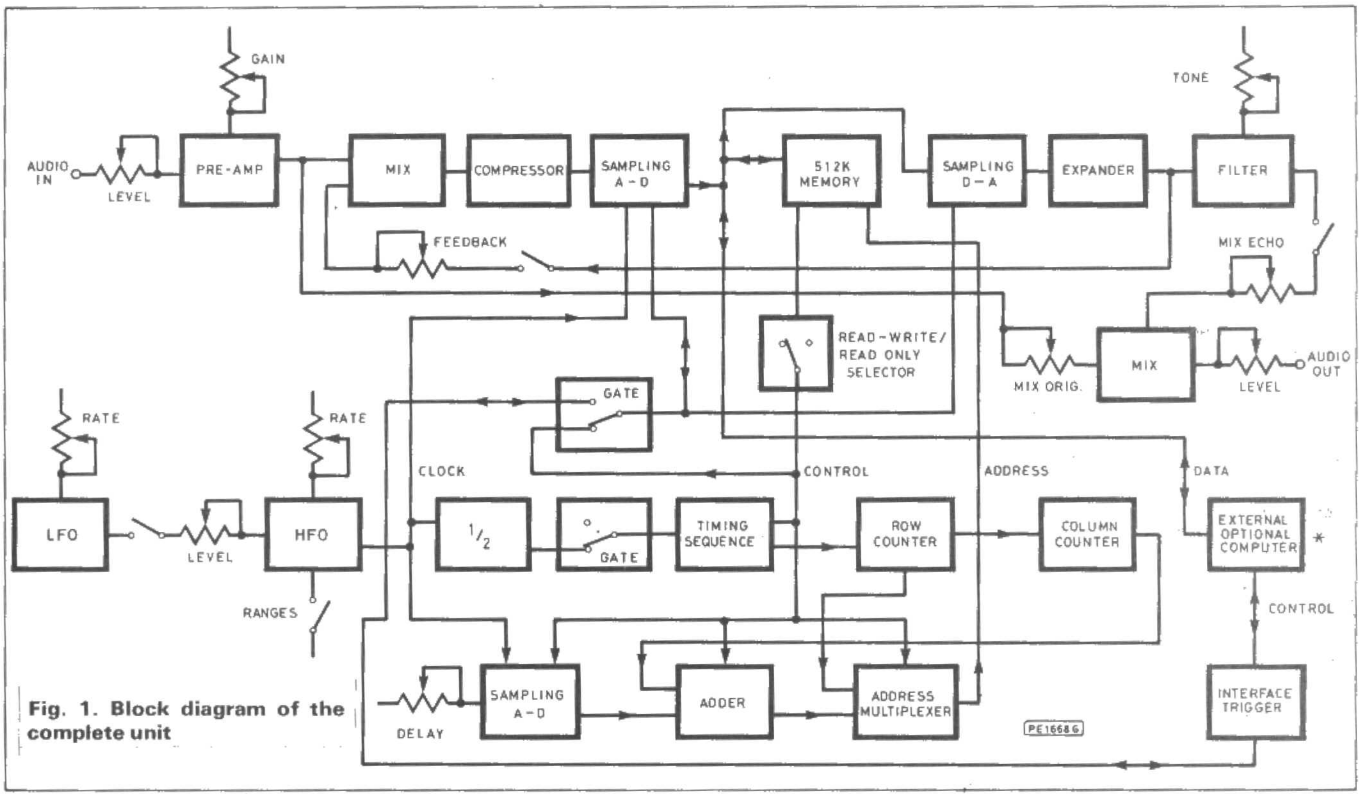


Fig. 1. Block diagram of the complete unit

BLOCK DIAGRAM

In addition to the main blocks already referred to, it will be seen that other facilities are also catered for. There is a variable level and gain input preamp, a compressor to limit the dynamic range of the signal, so effectively increasing the data storage capacity, and an expander to restore the range. The Read Only selector enables a loop of data in the memory to be constantly repeated, and the pitch and duration varied.

The inclusion of the external computer and interface trigger blocks, allows the unit to be used with its own memory, or with that of a separate computer. It is not necessary though to own a computer in order to use the delay unit, as its own internal memory makes it self-contained.

INPUT PRE-AMP & MIXER

In Fig. 2. an audio signal is brought into the initial level control VR1, and can come from a wide variety of sources, such as high output microphones and musical instruments, cassette recorders, effects units, and mixers. Within reason the input can be of fairly indiscriminate level, but in order to retain good signal to noise characteristics, should preferably already be at a level between about 1V and 4V pk-pk.

Higher levels can be accepted as VR1 can reduce the level. The preamp stage IC1a has a gain controllable by VR2,

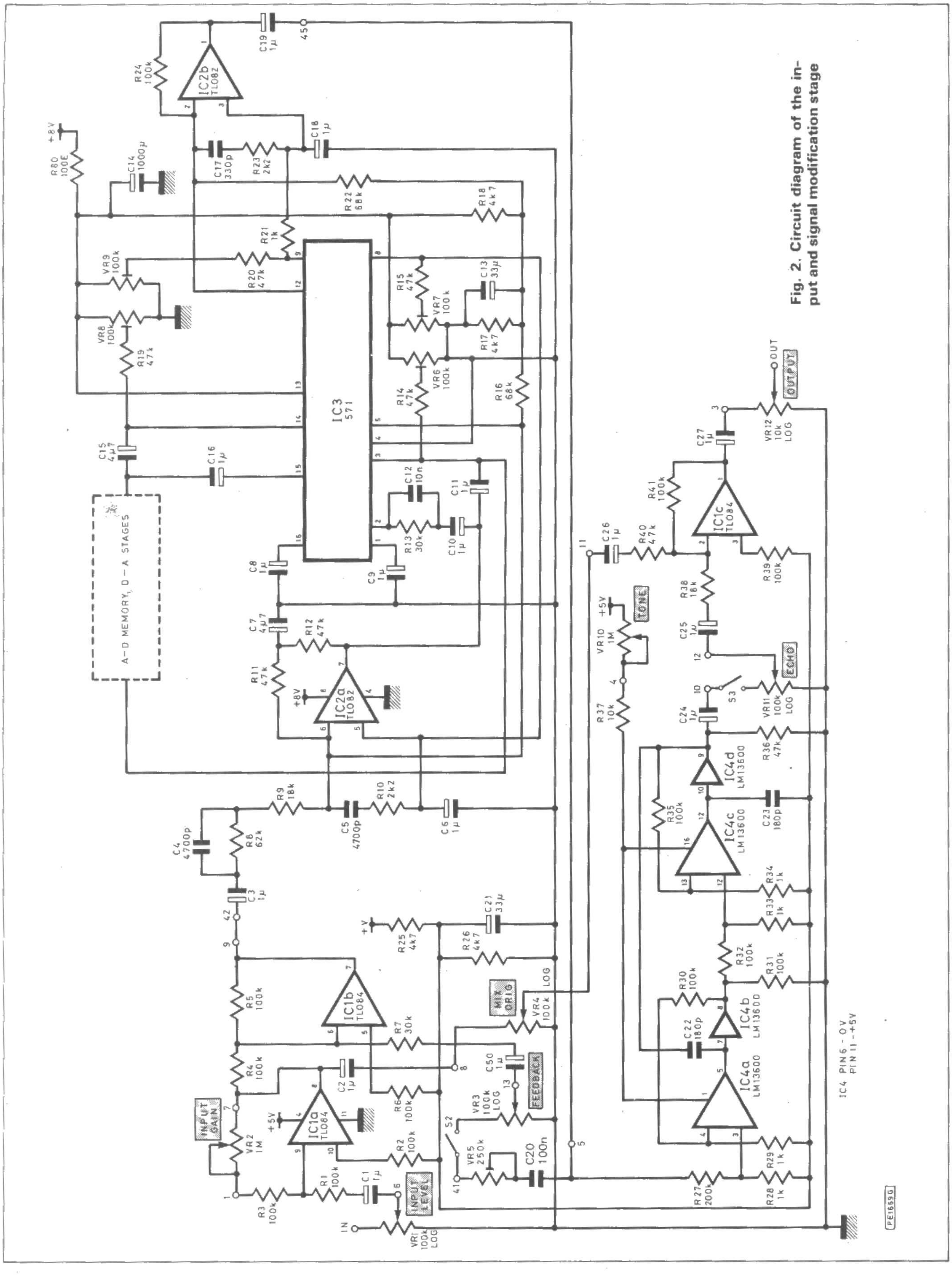


Fig. 2. Circuit diagram of the input and signal modification stage

to set a gain factor of between 1 and 10, but remember that any noise present in the signal will be amplified if VR2 is increased. From IC1a the signal is split, part going to the final output mixer via VR4, the rest going to IC1b which also mixes in delayed signals fed back via VR3.

COMPANDER

A compander is a combination of two circuits, one a compressor, and the other an expander. The idea is to compress the overall signal range so that more can be put through a processing unit without overloading it, and then to restore to the original range by an equivalent expander. Ignoring the effect of the intermediate processing unit, the output signal will be the same as the original. Compressing the range is not the same as reducing the level, for in overall level reduction already low level signals will be lost and cannot be regained by increasing the volume.

Table 1. shows the results obtained with this unit. Column 1 shows several readings taken of a signal with its dynamic range covering 10mV to 4V, a range of 400 to 1. This goes through the compressor which produces an output level of 100mV for 10mV fed in, and 3V for 4V fed in. The dynamic range has now become 30 to 1, as shown in Column 2. A level reduction occurs at the A to D converter, and the output from the D to A unit is in Column 3. The signal then goes through the expander and is restored to the original 400 to 1 range as seen in Column 4.

INPUT TO COMPRESSOR	*OUTPUT FROM COMPRESSOR*	*INPUT TO EXPANDER*	*OUTPUT FROM EXPANDER*
10mV	100mV	70mV	10mV
20mV	180mV	100mV	20mV
50mV	300mV	180mV	50mV
100mV	400mV	220mV	100mV
200mV	600mV	360mV	200mV
500mV	1V	550mV	500mV
1V	1·4V	780mV	1V
2V	2V	1·1V	2V
3V	2·5V	1·3V	3V
4V	3V	1·5V	4V

Table 1. Compander stage voltage levels

Without the companding process it would be necessary either to accept a lower dynamic range, or to use enlarged A to D and D to A converters, plus extra memory chips. For compression the signal passes through IC2a and to half of the compander chip IC3. This detects the signal level, and reduces its gain as the level increases, making feedback adjustments to IC2a. After processing, the signal then comes to the second part of IC3, which also detects the level, and makes the necessary gain changes in conjunction with IC2b in order to restore the range. VR6 to VR9 linearise the waveform and optimise d.c. bias levels.

PRE-EMPHASIS

In any clock controlled sampling unit, it is at some stage after processing, necessary to eliminate the residual sampling steps by filtering. In the act of filtering out high frequency sampling steps, a certain amount of upper signal frequency is also lost. This can be partly compensated for by emphasising upper frequencies of the original signal before processing, so that after filtering not too much overall loss occurs. Pre-emphasis is given here at the compression stage, and is essentially determined by C4 and C7. C5 limits the maximum frequency range emphasised to reduce interaction at normal sampling rates. Partial de-emphasis is given at the expander by C17, but the filter does the main job. Photos 1 to 3 give some idea of the effect.

EMPHASIS PHOTOS

A triangle waveform is used for illustrative clarity, and although it looks like a single frequency, in fact higher frequency harmonics are also present. In itself a 100Hz signal is below the pre-emphasis point, but the implicit higher harmonics of the waveform peaks are shown to be modified. At 1kHz, the signal is partly in and partly out of the emphasis range and is shown to be notably changed. At 10kHz there is barely any obvious shape change, though a slight rounding is apparent due to the restriction of the upper limiting capacitor.

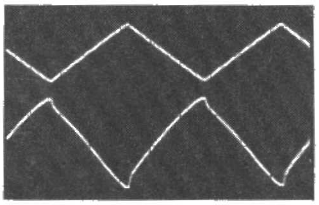


Photo 1. 100Hz

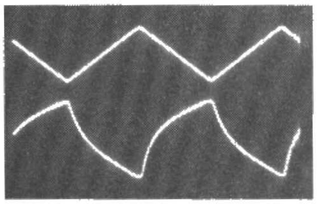


Photo 2. 1kHz

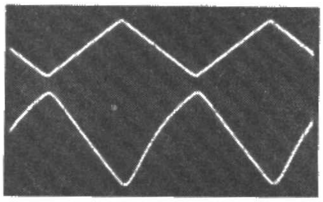


Photo 3. 10kHz

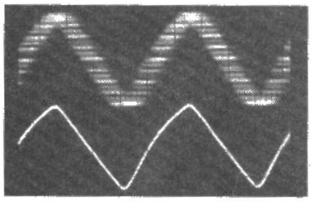


Photo 4. 10kHz

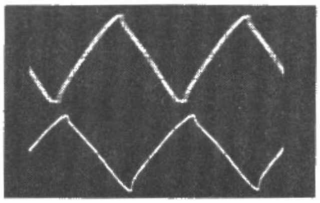


Photo 5. 100Hz

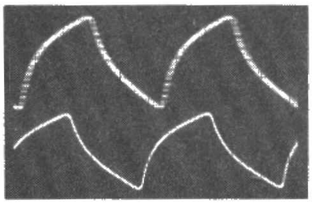


Photo 6. 1kHz

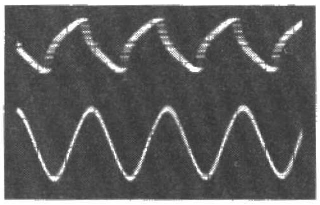


Photo 7. Slow rate

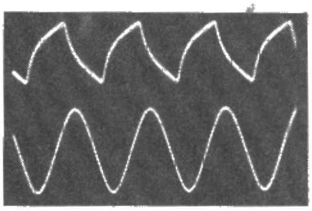


Photo 8. Fast rate

In Photos 4 to 6, the same emphasised frequencies are shown before and after sampling by the A to D and D to A converters. In photos 7 and 8, a 1kHz signal has been subjected to sampling at two different rates. The lower trace then shows the results of passing the reconstituted signal through the expander and the filter. The filtering has removed the sampling steps and reformed the shape. This has still slightly rounded off the tops of the waveform, but far less so than would be the case if pre-emphasis had not been given, when much greater rounding and level reduction would result from filtering.

FILTER STAGE

From the expander, the signal also goes to the low pass filter stage around IC4. It consists of two transconductance amps which in this configuration cause low pass filtering to occur at a range determined by the values of C22 and C23 and the current flowing at their control nodes as set by VR10.

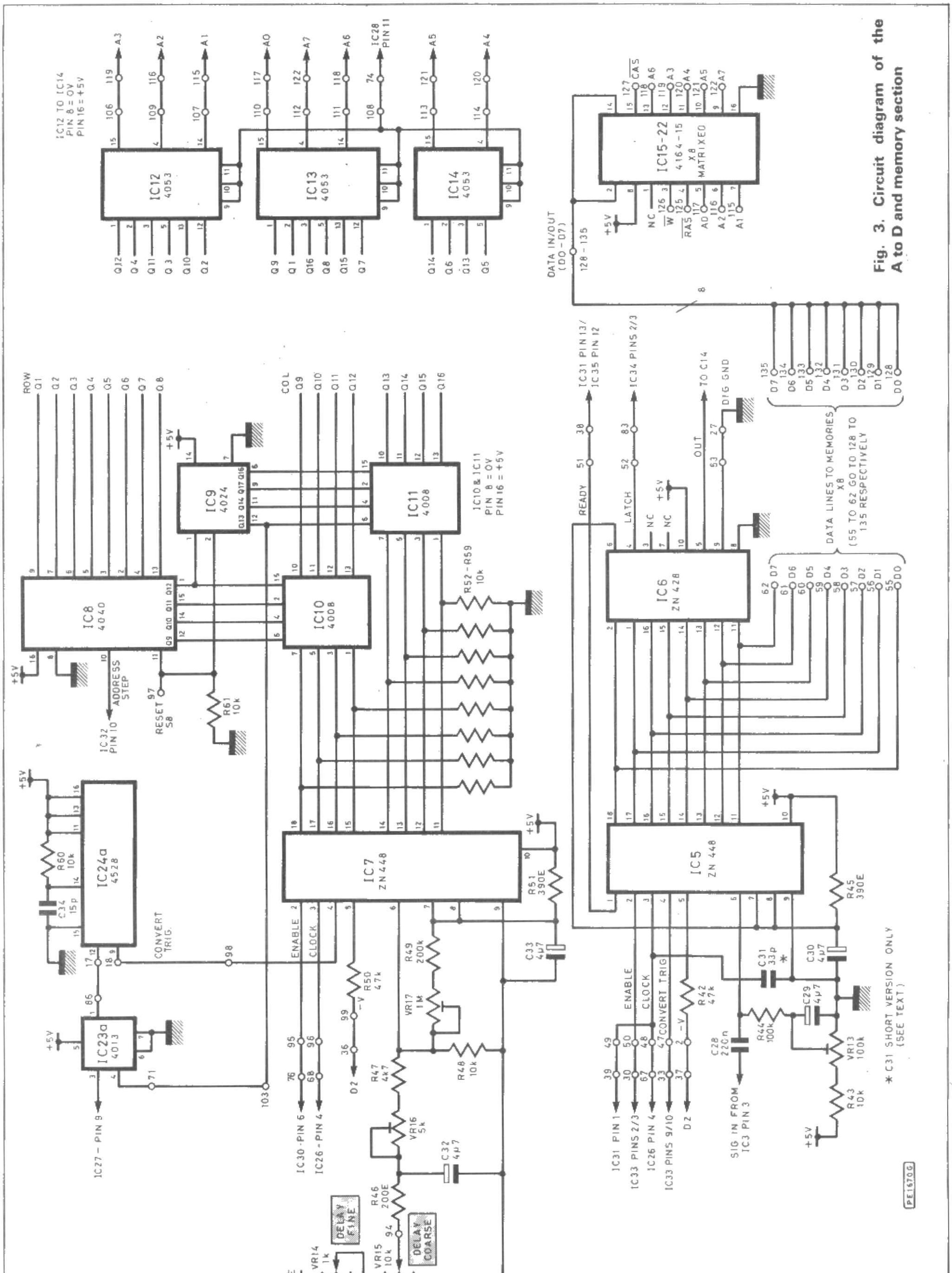


Fig. 3. Circuit diagram of the A to D and memory section

COMPONENTS . . .

Resistors

R1–R6,R24, R30–R32,R35, R39,R41,R44,R65	100k (15 off)
R7,R13	30k (2 off)
R8	62k
R9,R38	18k (2 off)
R10,R23	2k2 (2 off)
R11,R12,R14,R15,R19,R20, R36,R40,R42,R50,R75,R76	47k (12 off)
R16,R22	68k (2 off)
R17,R18,R25,R26,R47,R62, R63,R71	4k7 (8 off)
R21,R28,R29,R33,R34,R82	1k (6 off)
R27,R49,R72	200k (3 off)
R37,R43,R48,R52–R61,R64, R73,R74,R77–R79	10k (19 off)
R45,R51	390 (2 off)
R46,R69	200 (2 off)
R66	75k
R67	150k
R68	56
R70	1M2
R80	100
R81	10

All resistors ¼W 5% carbon

Potentiometers

VR1,VR3,VR4,VR11	100k log. mono. rotary (4 off)
VR2,VR10,VR18,VR20	1M mono. rotary (4 off)
VR5	250k skeleton
VR6–VR9,VR13	100k skeleton (5 off)
VR12	10k log. mono. rotary
VR14	1k mono. rotary
VR15	10k mono. rotary
VR16	5k skeleton
VR17	1M skeleton
VR19	100k mono. rotary

Capacitors

C1–C3,C6,C8–C11,C16,C18, C19,C24–C27,C50	1µ elect. (16 off)
C4,C5	4n7 polystyrene (2 off)
C7,C15,C29,C30,C32,C33, C36	4µ7 elect. (7 off)
C12	10n polystyrene
C13,C21,C35	33µ 6V elect. (3 off)
C14,C37,C47	1000µ 10V elect. (3 off)
C17	330p polystyrene
C20,C42,C43,C49,C51–C60	100n (14 off)
C22,C23,C39	180p polystyrene (3 off)
C28,C48	220n (2 off)
C31	33p
C34,C38,C40,C41 C44,C45	15p polystyrene (6 off)
C46	1n polystyrene

Semiconductors

D1,D2	1N4148 (2 off)
D3	5V1 400mW Zener
REC1	1A bridge rectifier
IC1	TL084
IC2,IC25	TL082 (2 off)
IC3	571
IC4	LM13600
IC5,IC7	ZN448 (2 off)
IC6	ZN428
IC8	4040
IC9	4024
IC10,IC11	4008 (2 off)
IC12–IC14	4053 (3 off)
IC15–IC22	4164–15 (8 off)
IC23	4013
IC24,IC32,IC35	4528 (3 off)
IC26	4046
IC27	4017
IC28	4071
IC29	4072
IC30	4075
IC31	4069
IC33,IC34	4066 (2 off)
IC36	7805 regulator

Switches

S1	n.o. push switch
S2–S7	s.p.d.t. (6 off)
S8,S9	d.p.d.t. (2 off)

Miscellaneous

- P.c.b.s (5 off)
- Fuse and holder
- LP1 mains neon
- Knobs for pots. (12 off)
- Rubber feet
- P.c.b. clips
- Transformer 6V, 6VA secondary
- I.c. sockets (various)
- Wire, solder, etc.
- Mono jack socket (2 off)

Constructor's Note:
A full kit of parts or separate p.c.b.s are available from **Phonosonics,** Dept. DDL, 8 Finucane Drive, Orpington, Kent BR5 4ED. (Send s.a.e. for details).

At the minimum resistance of VR10 the filter makes little differences to audio signals, but at maximum gives a 24dB cut at 1kHz, and a 50dB cut at 10kHz. As will be seen in the sampling frequency section, the frequency of the controlling clock can be varied as one method of varying the amount of delay. As the controlling frequency reduces, so a lower band pass range is required to clean up the sampled waveform. Hence the choice of manual control. The filter can of course also be used as a treble control.

OUTPUT MIXER

The processed signal from the filter can be switched in or out by S3, and its level controlled by VR11. From there it goes through the mixer stage at a gain of 5, and then to your usual amplifier, cassette recorder etc, with the final output level controlled by VR12. At this stage, the original signal as determined at IC1a can be brought in via VR4, for which route IC1c gives a gain of 2. Selection of effects,pass or bypass can be selected, together with the choice of balanced mix of original and processed signals.

A TO D AND D TO A

The A to D conversion in this unit is performed by an 8-bit sampling chip IC5 (Fig. 3.). The analogue signal comes from the compressor to pin 6 of IC5. The conversion is controlled by two sources, a pulse to start each conversion and a clock frequency to control its rate.

Upon receipt of the negative going convert trigger on pin 4, and during the next eight clock pulses on pin 3, it successively calculates the equivalent binary representation of the signal voltage present. During the conversion, the binary output is held closed in a high impedance state by a positive voltage on pin 2, and pin 1 is automatically low. Upon completion of the conversion pin 1 goes high, but the output remains closed until enabled by the control voltage on pin 2 going low. The binary output then corresponds to a decimal number in the range 0 to 255. The signal level must therefore be within a range so that the lowest level should produce an output corresponding to decimal zero, binary 00000000, and the maximum corresponding to decimal 255, binary 11111111.

If the signal is outside the range, the output remains at its equivalent limit of 0 or 255. The analogue input to IC5 is a.c. coupled via C28, and VR13 applies a d.c. bias so that in the absence of a signal the binary output corresponds to approximately the half way level of decimal 128, binary 10000000. With the outputs of IC5 enabled, the data is suitable for storing in the unit's memory, or that of a computer.

IC6 performs the conversion from binary back to an equivalent voltage. The inputs are directly coupled both to the memory, or computer, and also to the A to D chip, but the timing sequence ensures that IC5 and IC6 are never open simultaneously, but only at the correct point in the Read or Write modes. The conversion of binary data to a voltage is practically instantaneous and needs no controlling clock. However IC6 will only accept data during a negative going latch pulse on pin 4. It then reads the data, and stores it until the next latch pulse resets the data to another level. Both IC5 and IC6 are supplied by a common reference voltage from R45 and C30 so the analogue inputs and outputs track each other with similar voltage levels. C31 on IC5 can be ignored for the moment.

SAMPLING STEPS

The ratio of signal to sampling frequency should ideally be high in order to achieve greater definition of the waveform. Theoretically though it is usually accepted that a sampling rate of between two and three times the signal frequency is adequate. Thus a frequency can be represented by only two or three sampled steps per cycle. This is fine if the sampled and sampling frequencies are synchronised. In practise though this cannot be done for an audio signal as it is usually constantly changing in frequency and amplitude. This means that sampling takes place at different points on the waveform slopes on each cycle. When reconverted back to analogue these different sampling points will reproduce the same frequency, but the amplitude will change to correspond to the minimum and maximum sample numbers. The result of this is an additional sub harmonic frequency. Obviously then the closer the sampled and sampling frequencies are to each other, so a greater sub harmonic effect is produced. Higher sampling rates are needed to produce a cleaner end result. Computer printouts of the effects of sampling rates are shown in Fig. 4. to Fig. 6.

By deliberately using sampled and sampling frequencies close to each other, the sub harmonics can be used for special effects, such as bell sounds (store a single frequency closely matched to clock, then play back at a slower speed). Photos 9 and 10 show oscillograms of two practical examples of adverse clock to audio frequency relationships.

Despite the sub harmonic generation, for musical purposes a sampling rate of 12kHz to 15kHz produces very acceptable results, and when using the prototype at its maximum sampling rate of 67kHz, the bandwidth is quite easily at least 15kHz. Anyway, in many instances a bandwidth of even 3kHz is satisfactory for musical effects units with the processed signal, though the original should usually be retained at close to its original bandwidth. Note though that a bandwidth of 3kHz does not mean that everything above 3kHz is lost, just that attenuation of frequencies above that point begins to be noticeable, but they will continue to be heard quite well up the spectrum, depending on the steepness of the filter cut off.

MEMORIES

As we have seen, the analogue signal has been sampled by IC5, and an 8-bit binary equivalent obtained. Each of these bits is to be stored in a separate memory chip. Eight are needed, (IC15 to IC22) and each can store 65536 bits of data. If the memories are filled up a bit at a time at a rate of 15kHz, the maximum delay between the first and last bits is approximately 4·36 seconds with a frequency bandwidth of 5kHz. In air at 0°C sound travels at 1120 feet per second, so this delay is the equivalent of the signal travelling 4883 feet! Compare this to an average spring line length.

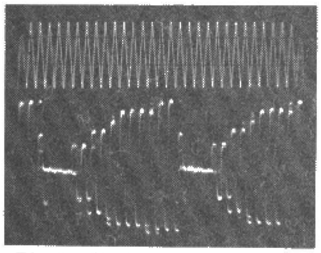


Photo 9. Sample rate too low

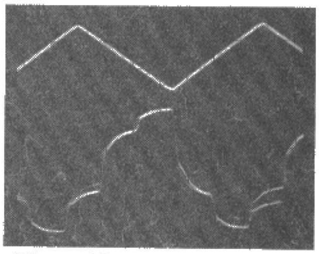


Photo 10. Audio frequency close to sample frequency

Despite the apparent complexity of the manufacturer's timing charts, for this audio application the timing sequence is quite simple. Each memory has eight address lines, three control lines, and two data lines, one in and one out, which in this instance are connected. The address and control lines are common to each memory and so are matrixed. Only the data lines retain their separate identities on each chip. As expected the address lines tell the memory where to put or fetch data. The chip is clever and the 16 address bits needed can be split into two groups of eight. 2^8 is 256, 256 × 256=65536, so all addresses are catered for.

One group is referred to as the Column address and the other the Row address. When the RAS control is activated, the 8-bit address is assumed to be a row, when CAS is activated, the address is assumed to be a column. The third control node tells the chip whether it is to Write the data into itself, or to Read it back. These timing instructions are also synchronised with the needs of the A to D and D to A converters, so that the correct sequence is maintained.

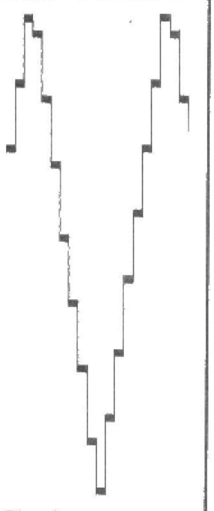


Fig. 4

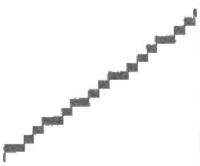


Fig. 5

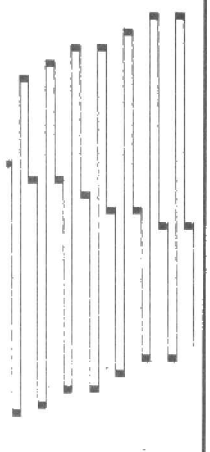


Fig. 6

Fig. 4. 1kHz sampled at 15kHz

Fig. 5. 100Hz sampled at 15kHz (section only).

Fig. 6. 5kHz sampled at 15kHz

NEXT MONTH: More circuit details including: delay selection, master clock oscillator and address counter.

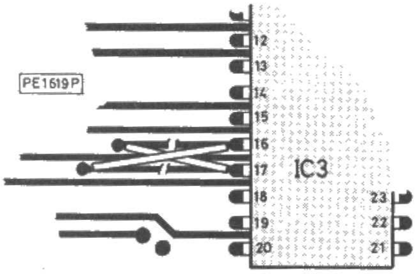
Low Cost

BBC Speech Synthesiser Update

THERE has been a massive response to the BBC Speech Synthesiser project published in March 1985. Unfortunately there have been a number of problems which have been brought to our attention by some of our readers.

Firstly, to put your mind at rest, the p.c.b. and component layout on page 32 is correct and there should be no problems with the hardware of the actual unit. However, there are, apparently, a number of variations in both the operating system and p.c.b. of the BBC Computer itself. Also the software listing published on page 34 of the March article has some printing errors and pin 4 on the circuit diagram (page 31) should read pin 5.

Fig. 1. Modification to the BBC Computer p.c.b.



CUT THROUGH TRACKS FROM PINS 16 &17 & LINK AS SHOWN USING INSULATED WIRE

MODIFICATION

As far as the variations in the actual BBC microcomputer are concerned, it is difficult to say what effects they will have upon the operation of the Speech Synthesiser without knowing the exact model and operating system used. We have, however, found out that some earlier models of the BBC had the READY and INTERRUPT lines transposed on their p.c.b., from IC3 to IC99. This fault may be overcome by cutting the tracks on the topside of the board from pins 16 and 17 and replacing them with cross-over wires on the underside as shown in the diagram.

The program listing shown here is a printout of a working project fitted to the BBC model B which has the operating system 1·20 fitted and an issue–4 p.c.b. If you have a different model, the Speech Synth should still work with some slight modification to the software but if there are any problems then it is suggested that you consult your dealer or Acorn themselves who should be able to give any details of any faults or modification in the computer hardware.

It also seems that there are a number of differences between computers fitted with, apparently, the same operating system and differences in versions of BBC BASIC. Therefore, we suggest that you thoroughly check the hardware of your Speech Synthesiser Project and if you still have problems, make further investigations into software.

```
L.
    5 REM KINDLY PRINTED OUT BY LANSDOWNE COMPUTER CENTRE, POOLE, DORSET.
   10MODE 7
   20DIM name$(9)
   30DIM allophone$(9)
   40PRINT TAB(6,2);"SPEECH DEMONSTRATION PROGRAM"
   50PRINT TAB(6,3);"============================"
   60REM title$ IS ALLOPHONE STRING FOR TITLE
   70title$="7IS2C'GPX/7Mq1%xFDIg5=gZP"
   80PROCspeak(title$,1)
   90REM SET UP USER DEFINED KEYS
  100*FX225,128
  110*FX226,138
  120FOR index%=0 TO 9
  130allophone$(index%)=CHR$(0)
  140PROCmenu(index%)
  150NEXT
  160speakmode=FALSE
  170REPEAT
  180IF speakmode THEN PROCgetword ELSE PROCupdate
  190UNTIL FALSE
  200END
  210REM PROCupdate ALLOWS MENU TO BE ALTERED
  220DEF PROCupdate
  230PRINT TAB(2,23);"Type 'S' for Speech mode."
  240INPUT TAB(2,17);"WORD NUMBER (0-9) ";reply$
  250PROCwipe(17)
  260PROCwipe(23)
  270IF reply$="S" THEN speakmode=TRUE:ENDPROC
  280index%=VAL(reply$)
  290IF index%>9 THEN 240
  300PRINT TAB(2,19);name$(index%)
  310PRINT TAB(2,20);
  320FOR count%=1 TO LEN(allophone$(index%))
  330PRINT;ASC(MID$(allophone$(index%),count%,1));" ";
  340NEXT
  350PRINT TAB(2,23);"Press (RETURN) to continue."
  360INPUT TAB(2,17);"WORD NAME ";reply$
  370IF reply$<>"" THEN name$(index%)=reply$
  380PROCwipe(17)
  390PROCwipe(23)
  400word$=""
  410REPEAT
  420PRINT TAB(2,23);"Press (RETURN) to continue."
  430INPUT TAB(2,17);"ALLOPHONE NUMBER (0-63) ";reply$
  440PROCwipe(17)
  450IF reply$<>"" AND VAL(reply$)>-1 AND VAL(reply$)<64 THEN word$=word$+CHR$(V
AL(reply$))
  460UNTIL reply$=""
  470IF word$<>"" THEN allophone$(index%)=word$
  480PROCmenu(index%)
  490PROCspeak(allophone$(index%),0)
  500FOR count%=19 TO 23
  510PROCwipe(count%)
  520NEXT
  530ENDPROC
  540REM PROCgetword GETS WORD FROM MENU CORRESPONDING TO KEY PRESSED
  550DEF PROCgetword
  560PRINT TAB(2,23);"Type 'A' to Alter menu."
  570PRINT TAB(2,17);"(SHIFT) to raise volume.f0-f9 ";
  580reply$=GET$
  590IF reply$="A" THEN speakmode=FALSE:PROCwipe(17):PROCwipe(23):ENDPROC
  600index%=ASC(reply$)-128
  610IF index%<0 OR index%>19 THEN 580
  620IF index%>9 THEN loud=TRUE:index%=index%-10:ELSE loud=FALSE
  630PROCspeak(allophone$(index%),loud)
  640ENDPROC
  650REM PROCmenu PRINTS ONE LINE OF MENU SELECTED BY index%
  660DEF PROCmenu(index%)
  670PROCwipe(index%+6)
  680PRINT TAB(2,index%+6);index%
  690PRINT TAB(6,index%+6);name$(index%)
  700ENDPROC
  710REM PROCwipe ERASES ONE LINE SPECIFIED BY Y%
  720DEF PROCwipe(Y%)
  730PRINT TAB(0,Y%);SPC(40);
  740ENDPROC
  750REM PROCspeak OUTPUTS STRING TO SPEECH SYNTH
  760DEF PROCspeak(word$,loud)
  770IF loud THEN offset=&20 ELSE offset=0
  780A%=159
  790FOR count%=1 TO LEN(word$)
  800Y%=(ASC(MID$(word$,count%,1)) AND &3F)+offset
  810CALL &FFF4
  820NEXT
  830Y%=offset
  840CALL &FFF4
  850ENDPROC
```

Information regarding the BBC Computer is available from:

Acorn Computers Ltd., Customer Service Division, Cambridge Technopark, 645 Newmarket Rd., Cambridge.

Strictly

by K. Lenton-Smith

FOR READERS with access to a ZX Spectrum, here are listings of programs for both the constructor and those wishing to make better use of Chord Symbols.

I have taken into account the somewhat tedious nature of entering programs from the keyboard and so have made them as short as possible, avoiding even the simple complication of colour or user defined graphics. Once entered, save the programs so that they will auto-run when loaded (e.g., SAVE "CHORDS" LINE 1). They can be amended subsequently to suit the user's requirements—the compasses of Program 1 and 2, and perhaps for the addition of extra chords in Program 3.

DISTWIRE

Program One produces a table showing the method of distributing the various signals produced by the generator system. Frequency No. 1 is taken to be lowest 16′ *C* on pedalboard or 5-octave manual and the multiple pitches (including mutations) to be wired to each keyswitch are shown numerically.

Nine pitches per playing key is asumed to be the maximum that the constructor would aim for and the diagonal nature of the required wiring will become evident from the table. For example, it will be seen that signal No. 49 not only supplies the lowest *C* at 1′ pitch but eight other keys also.

Because of the 32-column limitation, symbols have been used to indicate the mutations; the last few lines remind the user of their meaning. The higher notes at 1′ pitch may well be almost inaudible and the generator may not cover them anyway. Any missing top frequencies may be substituted by connecting to the same key one octave lower (a processs known as 'breaking back').

ET TUNE

Program Two will print out a list of equal temperament tuning frequencies, its starting point again being 16′ *C* as in the previous program. By altering variable *y* to 16.351598 the program can be made to start at 32′ *C* if necessary.

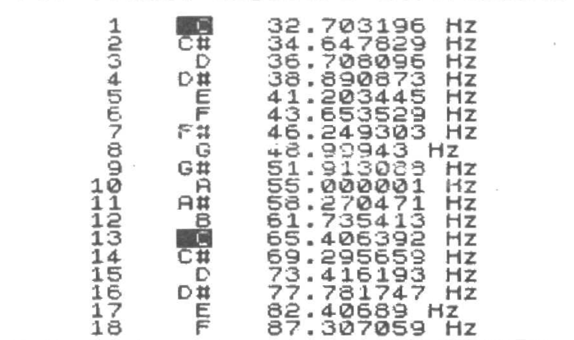
The Spectrum produces more decimal places than are strictly required when tuning with a digital frequency meter but making it work to a lesser number of places would have lengthened the chore of entering the program. The last part of the listing serves to remind the user of the compasses at various pitches.

A free phase instrument (where each generator is totally independent) is probably the ideal application as many separate tunings are required. Older divider instruments may use individual oscillators at the head of each divide-by-two string so the program can be used to set the 12 masters.

Program 1: DISTWIRE

```
 100 CLS
 110 PRINT TAB 4; INVERSE 1;"DIS
TRIBUTION WIRING BOARD"
 120 PRINT TAB 7;"by frequency n
umbers"
 130 PRINT AT 3,0;" 16´    8´ Q
4´ N  2´ T   L    1´"
 140 PRINT AT 3,0; OVER 1;"______
__________________________"„
 150 FOR n=1 TO 61
 160 IF n=1 OR n=13 OR n=25 OR n
=37 OR n=49 OR n=61 THEN PRINT ;
 INVERSE 1;"C>";
 170 PRINT TAB 2;n;TAB 6;n+12;TA
B 9;n+19;TAB 12;n+24;TAB 15;n+31
;TAB 18;n+36;TAB 21;n+40;TAB 25;
n+43;TAB 29;n+48
 180 NEXT n
 190 PRINT '"Where:- Q =  5-1/3´
 Quint"
 200 PRINT TAB 8;"N =  2-2/3´ Na
zard"

 210>PRINT TAB 8;"T =  1-3/5´ Ti
erce"
 220 PRINT TAB 8;"L =  1-1/3´ La
rigot"
```



```
  EQUAL TEMPERAMENT FREQUENCIES 

 For Tuning Keyboard Instruments

          1    C     32.703196 Hz
          2   C#     34.647829 Hz
          3    D     36.708096 Hz
          4   D#     38.890873 Hz
          5    E     41.203445 Hz
          6    F     43.653529 Hz
          7   F#     46.249303 Hz
          8    G     48.99943 Hz
          9   G#     51.913088 Hz
         10    A     55.000001 Hz
         11   A#     58.270471 Hz
         12    B     61.735413 Hz
         13    C     65.406392 Hz
         14   C#     69.295659 Hz
         15    D     73.416193 Hz
         16   D#     77.781747 Hz
         17    E     82.40689 Hz
         18    F     87.307059 Hz
```

Portion of the Spectrum's response when running Program Two.

Program 2: ET TUNE

```
 100 PRINT INVERSE 1;"  EQUAL TE
MPERAMENT FREQUENCIES "
 110 PRINT '" For Tuning Keyboar
d Instruments"
 120 LET y=32.703196
 130 LET x=EXP ((LN 2)/12)
 140 PRINT '"           1    C      ";y;
" Hz"
 150 FOR n=2 TO 109
 160 READ D$
 170 IF n<=9 THEN PRINT "  ";
 180 IF n>=10 AND n<=99 THEN PRI
NT " ";
 190 PRINT "        ";n;"    ";D$,"
";x*y;" Hz"
 200 LET y=x*y
 210 IF n=13 OR n=25 OR n=37 OR
n=49 OR n=51 OR n=73 OR n=85 OR
n=97 OR n=109 THEN RESTORE
 220 NEXT n
 230>DATA "C#"," D","D#"," E","
F","F#"," G","G#"," A","A#"," B"
," C"
 240 PRINT
 250 PRINT '" 16.35 Hz .... Lowe
st 32´ Pedal"
 260 PRINT " 65.41 - 2093 Hz ...
. 8´ Manual"
 270 PRINT "130.81 - 4186 Hz ...
. 4´ Manual"
 280 PRINT "261.63 - 8372 Hz ...
. 2´ Manual"
 290 PRINT "523.25 -16744 Hz ...
. 1´ Manual"
```

Current divider organs mainly use Top Octave Synthesisers where only one tuning is required to cover the instrument's compass. This is a convenient system but those blessed with perfect pitch can hear the tiny tuning descrepancies: these can be seen when a d.f.m. is used with the table.

CHORDS

Program Three takes longer to enter but will be most useful when extemporising from sheet music showing Chord Symbols. Ever got stuck when encountering a drastic key change in the 'middle eight'? If D♯m7 suddenly floors you, the computer will provide the answer.

It produces 96 of the commonly used chords in light music and a further 96 suggested inversions, giving arpeggios in each case. The inversions are such that they all fall into a similar compass and are suitable for left-hand accompaniment purposes without sounding either muddy or too strident.

The computer asks for the Chord Symbol to be input in two parts—first the ROOT and then the chord TYPE. All the black notes must be taken as sharps (as flats would have involved a longer program and the ♯ sign is on the keyboard) but either upper or lower case characters are accepted for the root.

To use the program, suppose the D♯m7 was required. When asked for the ROOT, enter D♯. The computer will then display a menu of chord types from which to choose and in answer to "TYPE of CHORD" enter m7.

The Chord Symbol is printed on the screen, the first inversion indicated on a two-octave keyboard and the actual notes played in slow arpeggio. The display remains for inspection until ENTER is pressed again: this will produce a practical inversion of the chord accompanied by a fast, repetitive arpeggio to simulate the sound of that inversion, bearing in mind the nasal quality of the square wave.

When R$ (the root) is supplied, variable *a* is set to a number between −12 and −1 according to that keynote. The chord type C$ directs the computer to lines that set up the required intervals, counting upwards from the root. For a Major Chord, simply press ENTER as its Chord Symbol consists of the root only. Line 480 onwards does printing and beeping for both chords.

Extra chords could be added, such as Major Sevenths or Major Ninths. The *Strictly Instrumental* article in the May 1980 edition briefly covered chord formation. The compass of the suggested inversion is alterable in lines 520–550 and by making line 510 read 'PAUSE 10' the computer can be made to skip quickly over the first inversion.

As it will eventually pay to memorise most of these chords for extemporising from Chord Symbols, experimenting with the program will show that there are a few redeeeming features. You well see that there are only three diminished chords (the constituents each sharing the same chord).

See if you can find the relationships between certain Major Sixths and Minor Sevenths—by comparing Cm7 and D♯6, for example. Until most of the 96 chords have been committed to (your!) memory, the program ought to help to find the more elusive ones that usually stop the left hand in its tracks. ★

Program 3: CHORDS

```
  10 CLS : PRINT "****** P.E. CH
ORD SYMBOLS ******"
  20 PRINT AT 4,0;"    C D EF G
A B▣ D EF G A BC    "
  30 FOR m=0 TO 3
  40 PRINT "          ■ ■  ■ ■ ■  ■ ■
■ ■ ■     "
  50 NEXT m
  60 INPUT "          ROOT of Chord
? ";R$
  70 PRINT AT 9,0;"
"
  80 PRINT AT 12,20;"          "
  90 IF R$="c" OR R$="C" THEN LE
T a=-12
 100 IF R$="c#" OR R$="C#" THEN
LET a=-11
 110 IF R$="d" OR R$="D" THEN LE
T a=-10
 120 IF R$="d#" OR R$="D#" THEN
LET a=-9
 130 IF R$="e" OR R$="E" THEN LE

 140>IF R$="f" OR R$="F" THEN LE
T a=-7
 150 IF R$="f#" OR R$="F#" THEN
LET a=-6
 160 IF R$="g" OR R$="G" THEN LE
T a=-5
 170 IF R$="g#" OR R$="G#" THEN
LET a=-4
 180 IF R$="a" OR R$="A" THEN LE
T a=-3
 190 IF R$="a#" OR R$="A#" THEN
LET a=-2
 200 IF R$="b" OR R$="B" THEN LE
T a=-1
 210 PRINT AT 15,0;"______________
______________________"
 220 PRINT
 230 PRINT "Enter (Major)","  m7
 (Minor 7th)"
 240 PRINT "  m   (Minor)","  m6
 (Minor 6th)"
 250 PRINT "  7  (Dom. 7th)","

 260>PRINT "  6  (Maj. 6th)","
dim (Dim. 7th)"
 270 PRINT "______________________
______________"
 280 PRINT AT 16,9;"Choose betwe
en"
 290 PRINT AT 12,0;"       CHORD
CHOSEN is ";R$;
 300 INPUT "          TYPE of Chord
? ";C$
 310 PRINT C$
 320 IF C$="" THEN GO TO 400
 330 IF C$="m" THEN GO TO 410
 340 IF C$="7" THEN GO TO 420
 350 IF C$="6" THEN GO TO 430
 360 IF C$="m7" THEN GO TO 440
 370 IF C$="m6" THEN GO TO 450
 380 IF C$="+" THEN GO TO 460
 390 IF C$="dim" THEN GO TO 470
 400 LET b=a+4: LET c=a+7: LET d
=a+12: GO TO 480
 410 LET b=a+3: LET c=a+7: LET d

 420>LET b=a+4: LET c=a+7: LET d
=a+10: GO TO 480
 430 LET b=a+4: LET c=a+7: LET d
=a+9: GO TO 480
 440 LET b=a+3: LET c=a+7: LET d
=a+10: GO TO 480
 450 LET b=a+3: LET c=a+7: LET d
=a+9: GO TO 480
 460 LET b=a+4: LET c=a+8: LET d
=a+12: GO TO 480
 470 LET b=a+3: LET c=a+6: LET d
=a+9: GO TO 480
 480 PRINT AT 9,a+16;"↑";AT 9,b+
16;"↑";AT 9,c+16;"↑";AT 9,d+16;"
↑"
 490 LET f=.3
 500 BEEP f,a: BEEP f,b: BEEP f,
c: BEEP f,d
 510 PAUSE 0: PRINT AT 9,0;"
"
 520 IF a<-7 THEN LET a=a+12
 530 IF b<-7 THEN LET b=b+12

 540>IF c>4 THEN LET c=c-12
 550 IF d>4 THEN LET d=d-12
 560 PRINT AT 12,0;"       An inv
ersion of ";
 570 PRINT AT 9,a+16;"↑": PRINT
AT 9,b+16;"↑": PRINT AT 9,c+16;"
↑": PRINT AT 9,d+16;"↑"
 580 PRINT AT 16,7;"
"
 590 LET f=.02: FOR n=0 TO 15
 600 BEEP f,a: BEEP f,b: BEEP f,
c: BEEP f,d
 610 NEXT n
 620 GO TO 60
```

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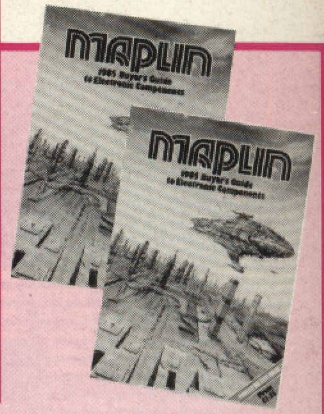
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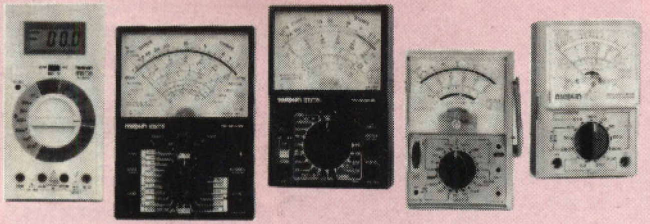

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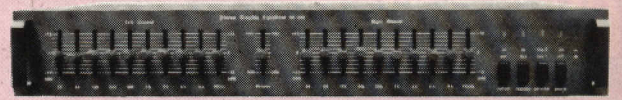

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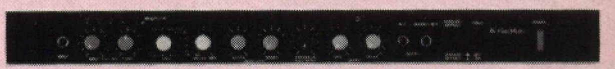

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